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AT HARVARD COLLEGE.
Vol. LIV, No. 1.

REPORTS ON THE SCIENTIFIC RESULTS OF THE EXPEDITION TO THE EASTERN TROPICAL PACIFIC, IN CHARGE OF ALEXANDER AGASSIZ, BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," FROM OCTOBER, 1904, TO MARCH, 1905, LIEUT.-COMMANDER L. M. GARRETT, U. S. N., COMMANDING.

XXXVI.

THE DINOFLAGELLATA: THE FAMILY HETERODINIIDAE OF THE PERIDINIOIDAE.

By CHARLES ATWOOD KOFOID AND ALASTAIR MARTIN ADAMSON.

WITH TWENTY-TWO PLATES.

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I. INTRODUCTION AND COLLECTIONS

The family Heterodiniidae comprises a number of relatively rare species of the Peridinioidae restricted to warm temperate and tropical seas. They are seemingly a depauperate group occurring mainly in the deeper levels of the illuminated zone. This is illustrated by the fact that only 17, or 7.1%, of our 240 station records of species of this family are from surface hauls. It was the custom on the Expedition to the Eastern Tropical Pacific to make subsurface hauls with No. 12 and No. 25 silk nets. The nets were lowered with the ship at slow speed to an estimated depth of 300 fathoms, towed for 20 minutes, and then brought to the surface with the ship still at slow speed. The catch was thus taken mainly at 300 fathoms, but intermingled with the plankton from 300–0 fathoms. It was this method of collection which gave the extraordinary representation of this family in the collections of this Expedition, as compared with their seeming paucity in the plankton collected by expeditions using vertical hauls for the collection of the microplankton.

This monograph includes only the family Heterodiniidae containing the two genera Heterodinium and Dolichodinium; the former with the three subgenera Sphaerodinium, Heterodinium, and Platydinium, and thirty-four species, of which thirty-three are from the collections of the Expedition; and the latter with one species only. Of the thirty-five species, five are new, as is also the genus Dolichodinium. Four of the five are from the plankton of the Expedition, and the fifth, *Heterodinium scotti*, was figured in the account of Scott's Antarctic Expedition, but taken in tropical waters "on the way out."

A full account of the route of the Agassiz Expedition to the Eastern Tropical Pacific in 1904–1905 will be found in the report of its Director, Alexander Agassiz (1906), together with maps and lists of collecting stations referred to in this monograph. A discussion of the methods of collection and examination of the microplankton will be found in the earlier monograph on the Dinophysoidae (Kofoid and Skogsberg, 1928). The principles followed in the treatment of the morphology, comparisons, variation, distribution, and frequency of occurrence, in this monograph, are essentially similar to those utilized in the monograph on the Dinophysoidae.

Acknowledgments

The authors are under deep obligations to Mrs. Josephine Rigden Michener for her aid in searching out these rare and elusive organisms, and to her skill in analyzing and drawing their complicated finer structure. The transfer to Ross-board was made by Mr. A. B. Streedain. The delicacy of detail and contour in the finished plates are due to his technical skill. For grants in aid, we are indebted to the late Alexander Agassiz, to the Carnegie Institution, through the late Alfred G. Mayor, and especially to the University of California, which has continuously aided this enterprise through grants by its Board of Research.

Acknowledgments are made to the Council of the National Academy of Sciences and to its Committee on Funds for Publication of Research for a grant in aid of the publication of this Memoir.

II. SYSTEMATIC ACCOUNT

The Family Heterodiniidae Lindemann

Heterodiniaceae Lindemann, 1928, pp. 95, 96, fig. 82.

These are Dinoflagellata of the Tribe Peridinioidae with the postcingular list reduced or lacking, but in which the anterior list is always present, is usually well developed, and is often supplemented by an angular projection of the body wall itself. In addition to the apical pore, which is usually deflected to the right asymmetrically, there is always present a peculiar, reniform or lobed, bordered pit or opening, located about midway between the apex and the girdle, to the right of, or in, the midventral suture of the epitheca. The type genus is Heterodinium Kofoid (1906a). The distribution of the family is in warm temperate and tropical seas.

Place of Heterodinium in the Peridinioidae

Lindemann (1928), in his "Pflanzenfamilien" monographic account of the genera of the Peridineae, established a separate family for the single genus Heterodinium, the Heterodiniaceae(=Heterodiniidae). He placed it in juxtaposition to his Ceratiaceae (=Ceratiidae) and Goniodomaceae (=Goniodomidae). The relations of the Heterodiniidae are obviously not very close to any other family. It is nearest, perhaps, to the Ceratiidae. It is linked to that family by the four apical plates of Dolichodinium, and its ventral pore is homologous to that of the subgenus Poroceratium in position, though not in relation to apical suture. On the other hand, the three apicals link it with the Goniodomidae. In the general forms of the body, the Heterodiniidae resemble those of the Peridiniidae more than those of any other family.

It differs from the Ceratiidae in having 6 precingulars instead of 5, and 6 or 7 postcingulars instead of 5; from the Peridiniidae in having 3 antapicals instead of 2 or 1; and from the Goniodomidae in having 6 or 7 postcingulars instead of 5. None of these families has the left anterior intercalary plate, and in none of them is the postcingular list degenerate.

The family Heterodiniidae contains two genera, Heterodinium Kofoid (1906a,) with 40 species, and Dolichodinium gen. nov., with 1 species. They differ in plate formula. Heterodinium has 3 apicals (1′–3′), 1 anterior inter-

calary (1ª), 6 precingulars (1″–6″), 6 (?) girdle plates (1–6), 7 postcingulars (1‴–7‴), and 3 antapicals (1⁗–3⁗). Dolichodinium has the formula 4′, 0ª, 6″, 6 (?), 6″ ′, and 3″ ″.

Heterodinium Kofoid

Peridinium Murray & Whitting, 1899, *partim*, p. 326–328; pl. 29, 30, see also *Heterodinium;* Hensen, 1911, *partim*, p. 174, fig. C, see also *Heterodinium;* Lindemann, 1928, p. 95–96, fig. 82.

Heterodinium Kofoid, 1906a, p. 341–368, pl. 17–19; 1907, p. 177–185, pl. 6–8; Kofoid & Michener, 1911, *partim*, p. 284–286, for *H. lineatum* see *Dolichodinium;* Jörgensen, 1911, p. 148.

Diagnosis: — Body usually slightly asymmetrical, strongly flattened dorsoventrally (subgenera Heterodinium and Platydinium), or sphaeroidal (subgenus Sphaerodinium), with two large antapical horns or spines (except in some species of Sphaerodinium); girdle submedian, lacking the post-cingular ridge entirely or in part; without lists; sulcus a short and very narrow groove; a reniform or circular pore present in a characteristic ventral area at the meeting of the mid-ventral and apical-precingular sutures of the epitheca; plate formula, 3′, 1ª, 6″, 6, or 7?, 7″ ′, 3″ ″, constant; theca hyaline, characteristically reticulated and porulate, rarely only porulate.

Widely distributed but rare in tropical and subtropical seas, a few only in warm temperate seas.

The type species is *H. scrippsi* Kofoid from the California Current off Southern California.

Organology: — Within the genus, defined as it is by definite and fixed characters of the thecal plates, there is a very wide range of modification of the general form of the body from almost perfectly spherical species like *H. sphaeroideum* (Plate 15, fig. 2), to the flattened and highly modified species like *H. gesticulatum* (Plate 16, fig. 37), the plate-like body of *H. inequale* (Plate 16, fig. 32), and the elongated tapering form of *H. blackmani* (Plate 15, fig. 25). The first typifies the subgenus Sphaerodinium (Plate 15, fig. 1–10) in that the body, though variously modified, is always circular at the girdle. In all the others there is a dorsoventral flattening, and, in most of them, a very characteristic flattening or excavation in the midventral region, almost always to be observed on the hypotheca. In the subgenus Platydinium (Plate 16, fig. 26–40) the epitheca is similarly modified to such an extent that it assumes a scoop-like form. Even in most of the spheroidal species the same character is suggested, and there is always some indication of torsion of the body in a clockwise direction manifested by the distal displacement, and in a few species by the overlap, of the girdle, an asymmetry possibly connected with the course followed in swimming. The body is almost always

widest at the girdle, *H. agassizi* (Plate 16, fig. 27) and several species of the *H. gesticulatum* (Plate 16, fig. 34–40) group being exceptions, and divided by it more or less equally.

The epitheca and hypotheca are thus subequal, and the girdle tends to be quite oblique, except in Sphaerodinium, with its ventral arcs dipping posteriorly.

The epitheca is usually rather less than the transdiameter in altitude, though exceeding it somewhat in some species, for example, in *H. blackmani* (Plate 15, fig. 25). Its apex is contracted into a definite apical horn only in the *expansum* group (Plate 15, fig. 11–15). It is usually very broadly and evenly rounded in all the species of the subgenus Platydinium, except in *H. fides*, where a deep precingular constriction sets off an expanded apical region. A differentiated apical horn, when present, is usually asymmetrical; in *H. spiniferum* (Plate 15, fig. 13) it attains a length of only 0.5 transdiameters. In *H. curvatum* and *H. blackmani* (Plate 15, fig. 24, 25) it is deflected to the right and the apical pore in Platydinium is often so deflected.

The hypotheca narrows behind the girdle more than the epitheca, and is characteristically asymmetrically bifurcated at the antapex into two large stout horns, somewhat after the manner of most species of Peridinium. However, in a few species, in fact in all of the subgenus Sphaerodinium (Plate 15, fig. 1–10), the antapex is rounded, evenly in *H. kofoidi*, *H. sphaeroideum*, and *H. doma* (Plate 15, fig. 1–3), asymmetrically in *H. calvum* (Plate 15, fig. 4). It bears spines instead of hollow horns in *H. minutum*, *H. obesum*, and *H. murrayi* (Plate 15, fig. 5–7).

The antapicals are much deflected to the left in *H. asymmetricum* (Plate 16, fig. 31) and to the right in *H. varicator* (Plate 16, fig. 39). The aberrant and unusual condition of the suppression of one of the antapicals, with compensatory adjustments elsewhere, occurs in two species. In *H. deformatum* (Plate 16, fig 35) it is the right horn thus deficient; in *H. sinistrum* (Plate 16, fig. 36) it is the left. A character unique in the Peridinioidae is found in the sinistral lobe of the *H. gesticulatum* group (Plate 16, fig. 34–40). This is the lateral extension on the left margin of the hypotheca at the level of the postcingular-antapical suture, and is accompanied by a compensatory reduction in volume on the right side of the hypotheca. Lateral denticles on one or both sides of the suture appear on the sinistral lobe in *H. mediocre* (Plate 16, fig. 36). With this sinistral extension on the hypotheca, there is often a dextral shifting of the apical pore of the epitheca.

The girdle which encircles the body at its widest part and is usually located

in the middle equatorial region is remarkable in being almost invariably deficient, wholly or in part, in its postcingular rim. This rim is sometimes developed only in the proximal part and fades away distally. The precingular rim, in contrast, is unusually prominent and steeply overhangs the shallow furrow which, if indented, is deepest anteriorly against the precingular rim. In extreme cases, for example in *H. gesticulatum* (Plate **16**, fig. 37), the whole girdle is incomplete distally. Outstanding lists are never developed in the margins of the girdle, though the rim may be a much thickened ridge. The girdle is sometimes perfectly horizontal, without displacement, but more usually it is a descending right spiral displaced distally by its width only. In only a few species, such as *H. murrayi* and *H. globosum* (Plate **15**, fig. 7, 10), is it widely displaced with its proximal end overlapping the distal. In many highly modified species the girdle is oblique, tilting ventrally; in *H. laticinctum* (Plate **16**, fig. 30) it is inclined at 45° to the horizontal.

The sulcus is invariably a very narrow groove, beginning in a small circular depression at the proximal end of the girdle, in which lies the flagellar pore, and extending with little or no expansion to the end, usually little more than half way to the antapex. The constancy of its form is rather remarkable. Its latera margins are usually thickened ridges, but spreading fins are never well developed. The sulcus lies in the deep midventral depression of the hypotheca. It never extends upon the epitheca.

The theca is definitely divided into plates which, by reason of the fineness of the suture lines in some cases, and in others of the heavy reticulation of the entire surface, are not always easily analyzed; but which prove to be constant in number in all cases of complete analysis, and to vary less in relative sizes than in most genera with species so diversified as in Heterodinium.

The plate formula is 3′, 1ª, 6″, 6 [or 7?], 7″ ′, 3″ ″.

At the apex is a small closing platelet, or perhaps more generally, a small open pore. Around it are three apical plates, 1′–3′, a large dorsal (2′), and two ventrals (1′ and 3′), separated by the prominent midventral suture attached to which is the platelet of the ventral area containing the ventral pore. There are six precingulars; two large ventral plates (1″ and 6″), two smaller dorsals (3″ and 4″), and two dorsolaterals (1″ and 5″). On the left shoulder is the characteristic, small, anterior intercalary plate (1ª), usually of nearly the same size as precingular 2″.

The number of girdle plates is uncertain. The sutures separating them are not clearly defined as in other genera. Their presence is sometimes suggested by

faint suture ribs and by the distribution of pores, as in *H. calvum* (Plate 1, fig. 1–3). Seven girdle plates (1–7) were found in *H. laticinctum*. The unusually large number of seven postcingulars occurs in this genus. Of these, 1″ ′ is small like the same plate in Gonyaulax and Amphidoma, 4″ ′ is usually middorsal, and 6″ ′ is larger than the others, reaching the antapex and forming part of the left horn in species in which antapical horns are present. In species with antapical horns, postcingular 7″ ′ seems to be more or less pushed up into the girdle in contact with the precingular 6″. Of the three antapicals, 3″ ″ is large, forming the dorsal side of the antapical region, while 1″ ″ and 2″ ″ are small and pushed to the right of the downward extension of postcingular 7″ ′.

At the meeting place of the four suture lines visible on the ventral face of the epitheca there is developed a characteristic ventral area, sometimes separable as a platelet, and usually distinguished from the rest of the theca by the absence of surface markings. It is circular, squarish, or elongated obliquely anteroposteriorly. It invariably contains a ventral pore which is circular or reniform, and located somewhere near the middle of the ventral area. The concavity of the reniform structure is usually directed more or less to the right. The function of both of these structures is entirely unknown. In *H. fenestratum* (Plate 7, fig. 5) a small canal runs from the pore posteriorly to a vacuole in the cytoplasm. This area is a very distinctive generic character.

The thecal wall is delicate in structure, thin, generally very hyaline, and in most cases has a very characteristic, beautifully reticulated structure. With few exceptions it is composed, apparently on both sides, inside and out, of a reticulation of large polygons, sometimes formed of rather fine lines, but usually of heavier bars which in some species with large reticulations are correspondingly heavier. It is, however, characteristic of this genus that the theca, because of its transparency, has a delicacy of structure unusual among armored dinoflagellates. There is something characteristic of the genus in the pattern of the reticulations. The polygons are mostly hexagons, not infrequently quadrilateral near suture lines; but the reticulations are never quite uniform and the sizes and shapes of the polygons therefore vary from one part to another. In almost all cases each has a single minute central pit or pore. Several pits in each polygon occur only in *H. fenestratum* (Plate 7, fig. 1). In a few species, for example in *H. calvum*, the only surface markings are the somewhat evenly distributed pores. It is possible, though hardly probable, that the few specimens which have been observed of these rather exceptional species were all young with the sculpturing incomplete. In others, notably *H. globosum* and *H. blackmani* (Plate 9, fig. 1–3) and in the

gesticulatum (Plate **12**, fig. 1–5) group, the sculpturing is characteristically irregularly and incompletely developed, being absent on some plates, and only partially covering others. This may be the result either of the recent formation of the theca or of resorbtion for hydrostatic adjustment. It is rather a curious phenomenon in that it is usually the right side (see *H. blackmani*, Plate **9**, fig. 1, and Murray and Whitting, 1899, pl. 29, fig. 6a, b, c) which is deficient. This is the same region as that in which the girdle also is less developed than in its left or proximal region. Fine reticulations, apparently secondary, may develop along the suture lines and on intercalary bands prior to ecdysis. These apparently proceed in development from the edges of the coarser primary reticulum into the widening, smooth intercalary zones.

Few observations have been made on the cell contents of living specimens belonging to this genus, which is not surprising, for the individuals are rare and do not often occur in surface collections in neritic plankton. The plasma is hyaline and colorless, vacuolated, and does not often completely fill the theca. The nucleus is of the usual dinoflagellate type, but often small and difficult to observe. Chromatophores are sometimes absent, and when present, their size is always small and number few. They are usually pale green or greenish yellow, irregularly spheroidal, and distributed at the periphery, or often aggregated into spheroidal, centrally located chromospheres. It is impossible with the few data at hand to say anything more definite about the cell contents of the living organisms and nothing whatever is known about their movements, reproduction, and other activities.

The absence of, or small number of, chromatophores, and the extreme hyalinity of the whole organism may be correlated with its habitat in the lower levels of the light zone of the sea.

Reproduction: — Nothing is known of fission or encystment in this genus. The development of intercalary zones, as in *H. praetextum* (Plate **7**, fig. 3), *H. blackmani* (Plate **9**, fig. 1), *H. curvatum* (Plate **9**, fig. 5, 6), and *H. doma* (Plate **1**, fig. 1–3), is suggestive of asexual reproduction by binary or multiple fission after ecdysis, as in Peridinium, rather than by binary fission accompanied by skeletal fission, as in Ceratium. The occurrence of intercalary zones, though rare in our material, renders this hypothesis quite probable and its probability is increased by the purely negative evidence of the entire absence of any trace whatsoever of a fission line in all specimens thus far examined.

Occurrence: — The occurrence (Plates **13**, **14**, and **17**, fig. 41) of the many and varied members of this large genus is very remarkable in that all of them, without

exception, are relatively extremely rare and very meagerly represented, as far as is known, in all seas, except those explored by this Expedition. Indeed, of the thirty-nine species, only twelve have been found outside the Pacific. All but seven of the known species, namely, *Heterodinium crassipes*, *H. inaequale*, *H. kofoidi*, *H. pavillardi*, *H. scotti*, *H. sphaeroideum*, and *H. trirostre*, are present in our collections. This seeming limitation is, however, probably only a function of the degree of exploration rather than a regional predilection or limitation.

The genus is represented (Plates **13**, **14**, Plate **17**, fig. 41) at sixty-one (48%) of the 127 stations (Plates **13**, **14**), with 10, 12, 12, 13, 12, and 2 stations on the six lines of the Expedition. These are distributed over the following regions: two (4580, 4583) are in the California Current; seven (4587, 4590, 4594, 4596, 4604, 4605, 4609) in the Mexican Current; four (4613, 4634, 4637, 4638) in the Panamic Area; ten (4647, 4648, 4650, 4657, 4659, 4664, 4667, 4669, 4670, 4676) in the Peruvian Current; twenty-seven (4679, 4680, 4681, 4683, 4685, 4686, 4687, 4688, 4701, 4705, 4706, 4707, 4709, 4711, 4717, 4719, 4721, 4722, 4724, 4728, 4730, 4732, 4734, 4736, 4737, 4739, 4740) in the South Equatorial Drift; eight (4689, 4691, 4692, 4695, 4697, 4698, 4699, 4700) in the Easter Island Eddy; two (4713, 4715) in the Galapagos Eddy; and one (4742) in the South Equatorial Current.

The great majority (223 of 247) of the station records, including those at Station 4580 two species, 4583 three species, 4587 one species, 4590 one species, 4594 three species, 4605 one species, 4609 one species, 4613 one species, 4634 two species, 4637 five species, 4638 four species, 4648 one species, 4650 two species, 4657 one species, 4659 two species, 4664 one species, 4667 one species, 4676 three species, 4679 eight species, 4681 four species, 4683 four species, 4685 two species, 4687 three species, 4689 three species, 4691 sixteen species, 4695 nine species, 4697 thirteen species, 4699 sixteen species, 4701 nineteen species, 4705 seven species, 4707 four species, 4709 three species, 4711 two species, 4713 two species, 4715 four species, 4717 two species, 4719 one species, 4721 two species, 4722 four species, 4724 eleven species, 4728 one species, 4730 five species, 4732 ten species, 4734 eight species, 4736 three species, 4737 five species, 4739 seven species, 4740 four species, 4742 four species, were in hauls from 300–0 fathoms; only seventeen records, viz.: — at Stations 4583 two species, 4590 two species, 4596 one species, 4604 one species, 4669 one species, 4680 two species, 4686 one species, 4688 one species, 4692 three species, 4698 one species, 4700 one species, 4706 one species, are from surface hauls, or at 21% of the total number of stations at which dinoflagellates were taken at the surface. At Station 4737 the genus was represented by three species from 100–0 fathoms, and at one station (4587) one species

was recorded at this depth. At seven stations, including records at Stations 4647 one species, 4670 two species, 4681 five species, 4689 four species, 4701 three species, 4724 three species, 4732 two species, it was taken in catches made by vertical hauls from 800–0 fathoms.

The range in surface temperatures at the 61 stations was from 66° F. in the Peruvian Current to 85° F. in the Mexican, and the average over all was 75.6° F.

The frequency for each species was almost always less than 1%. The records of frequency exceeding that amount are as follows: 3% *H. curvatum* (4692); 2% *H. curvatum* (4698); 1% *H. agassizi* (4657), *H. blackmani* (4707, 4739), *H. curvatum* (4739), *H. mediocre* (4715, 4742), *H. gesticulatum* (4689 two hauls, 4697), *H. globosum* (4691, 4692), *H. dispar* (4683, 4685, 4692, 4695, 4701), *H. milneri* (4676, 4724), *H. obesum* (4681), *H. rigdenae* (4695, 4732, 4737, 4742), *H. scrippsi* (4580), and *H. whittingae* (4691, 4715). In the remaining 236 station records of the various species, the frequency is less than 1%; that is, the specimens were found only after 100 other dinoflagellates had been met with in the course of the search by means of the mechanical stage of microscopical preparations of the plankton catch in formalin.

The data summarized above show, first, that the horizontal distribution of the genus Heterodinium in the Eastern Tropical Pacific is of the same general type as that of most other tropical genera, with the records few and scattered to the north, but reaching a very marked maximum to the north of Easter Island and where the route of the "Albatross" again crossed the South Equatorial Drift to the west towards Manga Reva and the Paumotu Archipelago. The rarity of the genus in the Peruvian Current is rather more decided than in the case of most other genera, there being records at only ten stations (4647, 4648, 4650, 4657, 4659, 4664, 4667, 4669, 4670, 4676) in the sixty stations in that current. Probably connected with this is its comparative scarcity in the Galapagos Eddy, part of the waters of which take their origin from the Peruvian Current. The predominance of occurrences and of speciation in the warmest regions of the tropics is quite marked in this genus.

The data regarding the vertical distribution in the case of most of the individual species is too meager for the drawing of detailed conclusions, but in most of the species, and for the genus as a whole, they show quite clearly that the optimum depth is not near the surface but somewhere in the deeper levels of the light zone. Kofoid (1906) states that, off the California coast near San Diego, no individuals were taken at the surface in many hauls over a period of several years, but only in vertical catches from between 165 and 40 fathoms to the sur-

face. He states that the absence of chromatophores, or their aggregation into chromospheres, is suggestive of occurrence in deep water with diminished light, as is also the extreme hyalinity of many of the species. It is perhaps because of their scarcity at the surface that so few species have been recorded from other tropical seas in other investigations. Collections on many of the earlier expeditions were made only at or near the surface; or with nets of coarser mesh, which permitted the escape of these relatively small organisms through the silk; or by vertical rather than intermediate hauls, such as were made on this expedition.

Evidence in the records of the Expedition is insufficient to demonstrate the restriction of any of the species to particular regions, or of any very significant differences in distribution, except in numbers, between one species and another. The restrictions of significance are of a more general type, such as the absence from the Peruvian Current.

The data with regard to coincident distribution are as follows: there were 19 species taken in the same haul at 1 station, 16 at 2, 13 at 1, 11 at 1, 10 at 1, 9 at 1, 8 at 2, 7 at 2, 5 at 4, 4 at 9, 3 at 11, 2 at 14, and 1 at 20. In the Eastern Tropical Pacific, the least rare of the species are *H. rigdenae* (23 records), *H. milneri* (19 records), *H. curvatum* (17 records), *H. gesticulatum* (16 records), and *H. globosum* (14 records). Seven are extremely rare, occurring only once: *H. angulatum* (4691), *H. leiorhynchum* (4697), *H. praetextum* (4740), *H. spiniferum* (4695), *H. sinistrum* (4638), and *H. superbum* (4699); or twice: *H. deformatum* (4724, 4736) in our records, and nowhere else with the exception of *H. leiorhynchum*, recorded twice by Murray and Whitting (1899) in the Tropical Atlantic.

The genus is seemingly even more rare in other seas, in number of species as well as in individuals, except for Hensen's (1911) computed numbers, and Schiller's (1916) reports of the abundance of *H. kofoidi* in surface waters of the Adriatic. Most of the few records are from tropical seas; from the Atlantic between 20° N. and 20° S., a total of eleven (excluding duplicates) species has been recorded, seven by Murray and Whitting (1899), four by Hensen (1911), and one by Karsten (1906). In the Indian Ocean, Karsten (1906) recorded but three species. From warm temperate seas, the only records are from the Mediterranean, *H. inequale* and *H. pavillardi* (as *kofoidi*) from the Gulf of Lyons (Pavillard, 1916), *H. kofoidi* and *H. crassipes* from the Adriatic (Schiller, 1916), and *H. leiorhynchum* from Naples (Entz, 1907, 1909). In the Pacific, in addition to the records here given, are those of Kofoid (1906), who found five species in the summer plankton off San Diego, California. One of these, *H. sphaeroideum*, has not been found elsewhere.

These records from other seas are too few to allow of a comparison with regard to the relative abundance of different species, between the Pacific and other oceans. But it may be noted that the majority of the most abundant species in our collections are among the widely distributed species elsewhere. For example, *H. gesticulatum*, one of the commonest in the Pacific, occurs also in the Atlantic, and *H. rigdenae* in both the Indian Ocean and Mediterranean. The relatively greater scarcity of species of this genus in other seas is doubtless in part only a function of the small number of collections made with fine silk nets from deeper waters, and of less complete searching of the catch of plankton.

To sum up, the numerous species of Heterodinium are eupelagic without exception; they are extremely rare; many appear to be stenobathmic in lower levels of the light zone; a few have been found to be very widely distributed, but probably all are essentially species of tropical and subtropical seas. As far as limited data go, their habitat is at least a fair distance below the surface, except for *H. kofoidi*, which was found by Schiller (1916) in abundance near the surface in the Adriatic.

Historical discussion: — The first species of Heterodinium to be figured is the one which we describe as *H. scotti*, presumably from the Tropical Atlantic, which Wilson (1905) sketched among the "Peridineans taken on the voyage out" of the "Discovery," on Capt. Scott's Expedition to the Antarctic. The genus was established by Kofoid (1906a) with thirteen species including *H. blackmani*, *H. doma*, *H. hindmarchii*, *H. trirostre*, *H. leiorhynchum*, and *H. milneri*, previously described by Murray and Whitting (1899) as species of Peridinium from the Tropical Atlantic, and also their *P. tripos* to which the new name *H. murrayi* was given. Five new species from the plankton of deeper waters of southern origin off San Diego, namely *H. sphaeroidcum*, *H. rigdenae*, *H. scrippsi*, *H. whittingae*, and *H. inaequale* were added, *H. scrippsi* being designated as the type of the new genus. *H. triacantha*, founded on *Gonyaulax triacantha* Jörgensen (1899), and also on *Ceratium hyperboreum* Cleve (1900), was incorrectly removed to Heterodinium from Gonyaulax where it properly belongs, by Kofoid (1906), who later (1911) restored it to Gonyaulax. Since then, nineteen more species and five forms have been described from the collections of this Expedition. In 1907a Kofoid described and figured as new *H. agassizi*, *H. calvum*, *H. curvatum*, *H. expansum*, *H. fenestratum*, *H. fides*, *H. gesticulatum* (with forma *typica*, *deformata*, *extrema*, and *mediocris*), *H. globosum*, forma *maculata* (of *hindmarchi* (Murray and Whitting) Kofoid), *H. laticinctum*, *H. longum*, *H. obesum*, *H. praetextum*, and *H. superbum*. In 1911 Kofoid and Michener added descriptions, but

no figures, of *H. angulatum*, *H. elongatum*, *H. laeve*, *H. lineatum*, *H. minutum*, and *H. spiniferum*.

The division into three subgenera, Euheterodinium (=Heterodinium), Sphaerodinium, and Platydinium, by Kofoid (1906) for the species then known, has proved to be suitable for the larger number now known and is adopted here.

In accordance with the Rules of Nomenclature (Blanchard, 1905) the name of the subgenus Euheterodinium proposed by Kofoid (January 6, 1906) must be abandoned and the subgeneric name Heterodinium utilized for the typical section of the genus in lieu of Euheterodinium. Owing to the differences in the plate formula and to the occurrence of fission of the theca in the species described by Kofoid (1911) as *Heterodinium lineatum*, we have removed this species from Heterodinium and established for it a new genus Dolichodinium (p. 00). In shape of theca, type of porulation, occurrence of fission, and plate formula, this species is difficult to allocate in Heterodinium which it resembles in girdle, sulcus, and plate 2′ which looks much like the intercalary plate 1^a pushed anteriorly so as to crowd a narrow extension to the apex.

Both references to, and additions to, the genus Heterodinium by other investigators are few in the literature subsequent to its establishment in 1906. Jörgensen (1911) cites its occurrence in plankton from the margin of the Gulf Stream at the Tortugas Station but did not designate the species observed. Hensen (1911, p. 174, fig. C) names some very crude and often inverted sketches of a miscellaneous array of species of various genera, all as species of Peridinium. Included in this incoherent jumble are several which recognizably belong in Heterodinium, namely his *Peridinium venter* (his fig. C, 7) which is *H. agassizi*, as he conjectures; his *P. pulchrum* (his fig. C, 8) which is *H. curvatum;* his *P. tristylum* which is *H. gesticulatum*, as he conjectures; and his *P. dentatum* (his fig. C, 16) which is *H. latieinctum*, or close to it. In 1916 (Jan. 8) Schiller described two new species from the Adriatic, *H. crassipes* (as *H. orassipes* in the description of his figure 1) and *H. kofoidi*, the smallest (20 μ) known species of the genus. Shortly afterwards, March 17, 1916, Pavillard (his pl. 2, figs. 1, 2) described from the Gulf of Lyon a species which he designated also as *H. Kofoidi*. Since Schiller had previously utilized this specific name a new name is necessary. Pavillard's species is accordingly here designated as *H. pavillardi*. In this same paper Schiller (1916, footnote, p. 209) quotes as *Heterodinium tripos* the species described by Murray and Whitting (1899) and later cited by Ostenfeld and Paulsen (1904) as *Peridinium tripos*. But this specific name is preoccupied in Peridinium,

thereby becomes a synonym, and the new name *murrayi* was assigned to it in Heterodinium by Kofoid (1906), as shown in the discussion of that species.

The nomenclatural changes introduced or utilized in this monograph are the return of *Heterodinium triacantha* (Jörgensen, 1899b) Kofoid to Gonyaulax (see Kofoid, 1911b); the renaming of *Peridinium tripos* Murray and Whitting (1899) as *H. murrayi* (see Kofoid, 1906a); the reduction of Hensen's (1911) *Peridinium dentatum* to a synonym of *H. laticinctum*, his *P. pulchrum* to *H. blackmani*, his *P. tristylum* to *H. gesticulatum*, and his *P. venter* to *H. agassizi;* the renaming of Pavillard's (1916) *H. Kofoidi* as *H. pavillardi;* and the reduction of *H. longum* Kofoid (1907a) to a synonym of *H. rigdenae* Kofoid (1906a) because the former is apparently only a form of the latter with wide intercalary bands.

In this monograph the following new species have been described: *Heterodinium dispar, H. asymmetricum, H. varicator,* and *H. sinistrum.* In addition *H. kofoidi* Pavillard (1916), preoccupied by *H. kofoidi* Schiller (1916), is renamed *H. pavillardi,* and *H. gesticulatum* forma *medioeris,* forma *extrema,* and forma *deformata* are raised to specific rank as *H. mediocre, H. extremum,* and *H. deformatum. H. scotti* is described from Wilson's (1905) unnamed figure.

A few scattered records of occurrences by Karsten (1906, 1907), Entz, Jr. (1907, 1909), and Pavillard (1915, 1916) constitute the remaining references in literature to the species of this interesting, but relatively very rare, genus.

The number of valid species in the genus Heterodinium, recognized in this monograph, is forty. Six of these, namely, *Heterodinium crassipes* Schiller (1916) and *H. kofoidi* Schiller (1916) from the Adriatic, *H. inaequale* Kofoid (1906a) and *H. sphaeroideum* Kofoid (1906a) from the California Current, *H. pavillardi* Kofoid (nom. sp. nov.) from the Gulf of Lyon, and *H. trirostre* (Murray and Whitting, 1899) Kofoid (1906a) from the Tropical Atlantic, were not found in the collections of this Expedition, leaving thirty-four here reported for the Tropical Pacific. In the following list of the forty species recognized by us as valid, the author and date for each is given, and the oceanic regions from which they have thus far been reported is also stated.

Valid Species of Heterodiniidae, with known Distribution and Number of Record Stations

Genus Heterodinium.

H. agassizi Kofoid (1907a). Tropical Atlantic (49) and Pacific (7).
H. angulatum Kofoid & Michener (1911). Tropical Pacific (1).
H. asymmetricum sp. nov. Tropical Pacific (4).

H. blackmani (Murray & Whitting, 1899) Kofoid (1906a). Tropical Atlantic (11), Indian (5), and Pacific (11).
H. calrum Kofoid (1907a). Tropical Pacific (8).
H. crassipes Schiller (1916). Adriatic (1).
H. curvatum Kofoid (1907a). Tropical Atlantic (20) and Pacific (17).
H. deformatum (Kofoid) (1907a). Tropical Pacific (2).
H. dispar sp. nov. Tropical Pacific (13).
H. doma (Murray & Whitting, 1899) Kofoid (1906a). Tropical Atlantic (1) and Pacific (5).
H. elongatum Kofoid & Michener (1911). Tropical Pacific (7).
H. exponsum Kofoid (1907a). Tropical Pacific (3).
H. extremum (Kofoid) (1907a). Tropical Pacific (6).
H. fenestratum Kofoid (1907a). Tropical Pacific (15).
H. fides Kofoid (1907a). Tropical Pacific (5).
H. gesticulatum Kofoid (1907a). Tropical Atlantic (16) and Pacific (16).
H. globosum Kofoid (1907a). Tropical Pacific (14).
H. hindmarchii (Murray & Whitting, 1899) Kofoid (1906a). Tropical Atlantic (12) and Pacific (10).
H. inaequale Kofoid (1906a). California Current (1).
H. kofoidi Schiller (1916). Adriatic (1).
H. laeve Kofoid & Michener (1911). Tropical Pacific (9).
H. laticinctum Kofoid (1907a). Tropical Atlantic (11) and Pacific (5).
H. leiorhynchum (Murray & Whitting, 1899) Kofoid (1906a). Tropical Atlantic (2), Pacific (1), and Mediterranean (1).
H. mediocre (Kofoid) (1907a). Tropical Pacific (7).
H. milneri (Murray & Whitting, 1899) Kofoid (1906a). Tropical Atlantic (11) and Pacific (19).
H. minutum Kofoid & Michener (1911). Tropical Atlantic (3).
H. murrayi (Murray & Whitting, 1899 as *Peridinium tripos*) Kofoid (1906a). Tropical Atlantic (4) and Pacific (6).
H. obesum Kofoid (1907a). Tropical Pacific (6).
H. pavillardi nom. sp. nov. Pavillard (1916) as *H. kofoidi*. Gulf of Lyons (1).
H. praetextum Kofoid (1907a). Tropical Pacific (1).
H. rigdenae Kofoid (1906a). California Current (1), Tropical Indian (1) and Pacific (23).
H. scotti sp. nov. Wilson (1905, as "Peridinean"). Tropical Atlantic (1?).
H. scrippsi Kofoid (1906a). California Current (1), Tropical Atlantic (2), Indian (1), and Pacific (10).
H. sinistrum sp. nov. Tropical Pacific (1).
H. sphaeroideum Kofoid (1906a). California Current (1).
H. spiniferum Kofoid & Michener (1911). Tropical Pacific (1).
H. superbum Kofoid (1907a). Tropical Pacific (1).
H. trirostre (Murray & Whitting, 1899) Kofoid (1906a). Tropical Atlantic (1).
H. varicotor sp. nov. Tropical Pacific (5).
H. whittingae Kofoid (1906a). California Current (1) and Tropical Pacific (11).
Dolichodinium lineatum (Kofoid & Michener) (1911). Tropical Pacific (2).

Species from other genera have been included in Heterodinium either as valid species or as synonyms. These, with their authors, dates, and status in this monograph, are distributed below in their other genera as follows.

Ceratium hyperboreum Cleve (1900c) = *Gonyaulax triacantha* Jörgensen (1899b) = *Heterodinium triacantha* (Jörgensen) Kofoid (1906a).
Gonyaulax triacantha Jörgensen (1899b) = *Heterodinium triacantha* (Jörgensen) Kofoid (1906a) = *Gonyaulax triacantha* Jörgensen, Kofoid (1911b).
Peridinium areolatum Karsten (1906, p. 150, pl. 23, fig. 18a, b) = *Heterodinium scrippsi* Kofoid (1906a).
P. blackmani Murray & Whitting (1899) = *H. blackmani* (Murray & Whitting) Kofoid (1906a).
P. dentatum Hensen (1911) = *H. laticinctum* Kofoid (1907a).
P. doma Murray & Whitting (1899) = *H. doma* (Murray & Whitting) Kofoid (1906a).
P. hindmarchii Murray & Whitting (1899) = *H. hindmarchii* (Murray & Whitting) Kofoid (1906a).
P. leiorhynchum Murray & Whitting (1899) = *H. leiorhynchum* (Murray & Whitting) Kofoid (1906a).

P. milneri Murray & Whitting (1899) = *H. milneri* (Murray & Whitting) Kofoid (1906a).
P. pulchrum Hensen (1911) = *H. curvatum* Kofoid (1907a).
P. tripos Murray & Whitting (1899) non Ehrenberg (1834) = *H. murrayi* Kofoid (1906a).
P. trirostre Murray & Whitting (1899) = *H. trirostre* (Murray & Whitting) Kofoid (1906a).
P. tristylum Hensen (1911) = *H. gesticulatum* Kofoid (1907a).
P. venter Hensen (1911) = *H. agassizi* Kofoid (1907a).

The following specific or other names have been used in the literature of the genus Heterodinium though the species in question may not have been assigned by its author to Heterodinium. These names have been discarded in this monograph for the reasons indicated. In so far as we can ascertain, none of them has been disposed of in any prior publication.

dentatum (Hensen, 1911, in Peridinium) = *H. laticinctum* Kofoid.
longum (Kofoid, 1907a, in Heterodinium) = synonym of *H. rigdenae* Kofoid.
orassipes (Schiller, 1916, in Heterodinium) = *lapsus* for *crassipes*.
pulchrum (Hensen, 1911, in Heterodinium) = *H. curvatum* Kofoid.
rigdunae (Karsten, 1907, p. 473, in Heterodinium) = *lapsus* for *rigdenae*.
typica (Kofoid, 1907a, in Heterodinium as *forma* of *H. gesticulatum*) = *H. gesticulatum* (Kofoid).

Synonyms were created by Karsten (1906) who published *Peridinium areolatum*, though at the same time stating its identity with *H. scrippsi*, and by Hensen (1911), when he published his *Peridinium tristylum* and *P. venter* and at the same time stated that they were probably identical with *Heterodinium gesticulatum* Kofoid and *H. agassizi*, respectively. Murray and Whitting also erred in using *Peridinium tripos* for a species when Ehrenberg (1834) had previously applied the same name in the same genus to a dinoflagellate now known as *Ceratium tripos*. Murray and Whitting's *P. tripos* is renamed *Heterodinium murrayi* by Kofoid (1906a). Pavillard (1916) described *H. Kofoidi* from the Gulf of Lyons, not knowing that Schiller (1915) had shortly before used the same name for a different species. On page 86 we designate in this monograph Pavillard's species as *H. pavillardi*.

Two names introduced into Heterodinium have been referred to other genera. Kofoid, in his original account (1906a) of the genus, included Jörgensen's (1899b) *Gonyaulax triacantha*, which Cleve (1900c) later described as *Ceratium hyperboreum*, in Heterodinium. In his later revision of the genus Gonyaulax, Kofoid (1911b) returned the species *triacantha* to Gonyaulax. In this monograph the species *Heterodinium lineatum* described by Kofoid and Michener (1911) is made the type species of a new genus, Dolichodinium.

Adaptive characters: — The more primitive species such as the *H. kofoidi* group retain the small size along with the spherical form, and thus maintain a high specific surface for flotation and do not develop the horns or marked reticulations. In the larger species such as the terminal members of the ortho-

genetic series (Plates 15, 16, fig. 1–39) the loss of specific surface due to the larger size is compensated for by the outgrowth of the apical and antapical horns, by the flattening of the expanded epitheca as in Platydinium, and by the development of rugose reticulations. There is also a considerable development of vacuoles in the cytoplasm of some of the larger species, such as *H. laeve*, (Plate 16, fig. 32) in the absence of surface rugosities. The larger species and the more highly specialized ones show a tendency towards asymmetry by curvature of the apical and antapical horns and by the scoop-shaped depression of the epitheca. These various modifications are devices to assist in flotation by increase of specific surface (horns and reticulations), by reduction of overweight (hydrostatic vacuoles), and by producing a wavering motion in sinking (curvature of outgrowths).

The characters of greatest systematic significance within the genus are the shape of the body, especially of the epitheca and apical horn, the length, shape and curvature of the antapicals, the structure of the girdle, the surface reticulations, the shape of plates 1^a and $7''$ ′, and the outline of the postmargin.

Relationships among the species: — In the speciation within the genus Heterodinium a wide range of diversity in form has occurred with at the same time a retention of the more fundamental generic characters, so constant that its members form a very well-defined and natural generic group. These characters are the plate formula and arrangement, especially the presence of 1^a, the anterior intercalary, the suppression of the postcingular ridge, the short sulcus, the ventral area on the epitheca with the included ventral pore, and the reticulate structure of the thecal wall, all of which features, except the last, are clearly expressed in all of the species. As a result, a subdivision of this genus into subgenera must deal mainly with form and proportions, must utilize characters which tend to intergrade, and must be of slight value except for convenience in treating so large a group.

The three subdivisions, proposed by Kofoid (1906a), are here recognized and the species are divided among these in the keys. They are, however, of unequal value, only one of them, the subgenus Platydinium, being a sharply set-off, natural group, its members being united by having a characteristically scoop-shaped epitheca, with the apex broadly rounded in ventral view, and by the agreement in other less striking characters such as antapical horns, asymmetry of midventral epithecal suture, and prominent ventral pore. This is probably the most specialized group, all its members being highly modified from the typical Peridinium-like form of body. The other two subgenera are also sepa-

rated on the basis of the form of the body, Sphaerodinium containing the rotund forms with circular cross-section, and Heterodinium those with more flattened form and tapering epitheca. Since these characters tend to intergrade among the species, their separation into the two subgenera is artificial, more or less arbitrary in some cases, and is made mainly for convenience in bringing out relationships.

In (Plate **15**, fig. 1–25, Plate **16**, fig. 26–40) outline sketches of all the known species have been arranged in the main according to increasing size and growing complexity of structure. All of the figures have been drawn to the same magnification. The groups conform to the three subgenera: (Plate **15**, fig. 1–10) belong to Sphaerodinium, (Plate **15**, fig. 11–25) represent Heterodinium, and (Plate **16**, fig. 26–40) Platydinium. Within the genus as a whole the species can be seriated in several sequences of orthogenetic type, each beginning with smaller and simpler species and culminating in ones of larger size, with more complex surface structure, and more extension of apical or antapical horns, or of both.

We recognize seven such series: in the subgenus Sphaerodinium, the *kofoidi* and the *minutum* groups; in the subgenus Heterodinium, the *expansum*, *leiorhynchum*, and *rigdenae* groups, and in the subgenus Platydinium, the *pavillardi* and the *gesticulatum* groups.

The subgenus Sphaerodinium is characterized by the spheroidal form of the body and no antapicals, or only small ones.

Within Sphaerodinium two orthogenetic series occur. The first, the *kofoidi* group (Plate **15**, fig. 1–4), contains but four species and is the most primitive one in the genus, starting with the minute sphaeroidal *H. kofoidi* (20 μ) (Plate **15**, fig. 1) and including *H. sphaeroideum*, *H. doma*, and *H. calvum* (75 μ) (Plate **15**, fig. 2–4), all of sphaeroidal shape. No apical or antapical spines or horns occur in this primitive series, though the highest representative, *H. calvum*, has an angular postmargin.

The second series, the *minutum* group (Plate **15**, fig. 5–10), is characterized by the presence of antapical spines or horns upon a spherical or spheroidal type of body with an apical horn also emerging in the species above the lowest representative. It includes six species, beginning with the small (40 μ) spheroidal *H. minutum* with minute solid spinules and no trace of an apical horn, and including *H. obesum*, *H. murrayi*, *H. milneri*, *H. superbum*, and terminating in the large *H. globosum* (117 μ) with stout hollow antapicals and well developed apical horn.

The subgenus Heterodinium (Plate **15**, fig. 11–25) is characterized by the tapering conical epitheca and well developed antapicals. Three series of species

occur in this subgenus; the *expansum* group (Plate **15**, fig. 11–15) with rotund body and emergent apical horn; the *dispar* series (Plate **15**, fig. 16–21) with elongated body and tapering but not constricted epitheca; and the *rigdenae* group (Plate **15**, fig. 22–25) with stout flattened epitheca with straight or rotund sides and no apical horn.

The *expansum* group (Plate **15**, fig. 11–15) contains five species, beginning with the medium-sized (105 μ) *H. expansum* with very rotund body and minute apical and antapicals, including *H. angulatum*, *H. spiniferum*, *H. fenestratum*, and terminating in the very large (240 μ), heavily reticulated, and much elongated *H. praetextum*, the largest species of the genus. This series represents the highest degree of Peridinium-like differentiation developed in the genus Heterodinium.

The *dispar* group (Plate **15**, fig. 20–25) contains six species, beginning with the small (72 μ) *H. dispar* with short epitheca, weakly developed antapicals, and slight reticulations; it includes in the ascending scale of differentiation *H. elongatum*, *H. leiorhynchum*, *H. hindmarchii*, and *H. curvatum;* and terminates with the large (240 μ) *H. blackmani*, all Peridinium-like in form and proportions. In this series occur some of the most elaborate developments of surface markings and suture differentiations in the whole genus.

The *rigdenae* group (Plate **15**, fig. 16–19) within the subgenus Heterodinium leads off in the direction of the subgenus Platydinium. In this group the epitheca develops from the conical to the inflated type with convex sides in ventral view. It begins with *H. rigdenae*, with a low epitheca, subconical in lateral view, and includes *H. crassipes* and *H. scrippsi*, terminating in *H. trirostre* with straight lateral margins and spreading antapical horns. In this latter respect it leads off towards the subgenus Platydinium. The accessory left antapical horn is found also in *H. milneri* of the *minutum* group.

The subgenus Platydinium (Plate **16**, fig. 26–40) has a very much flattened epitheca with convex sides and broadly rounded or expanded apex. It falls into two groups, the *pavillardi* group without sinistral lobe and the *gesticulatum* group with the lobe. The *pavillardi* group (Plate **16**, fig. 26–33) begins with the small (90 μ) *H. pavillardi* with low rounded epitheca and short asymmetrical antapicals and continues through *H. asymmetricum*, *H. inaequale*, and *H. laeve*. The last species is rather close to *H. mediocre*, the initial member of the *gesticulatum* group. A side line of species of increasing size, but with widely expanded, broadly rounded epitheca, and short, more closely approximated antapicals, includes *H. agassizi*, *H. whittingae*, and *H. laticinctum*. The tendency towards

lateral constriction of the epitheca, slightly evolved in *H. agassizi*, reaches a maximum in *H. fides*.

The most unique, grotesque, and most asymmetrical group is the *H. gesticulatum* series (Plate 16, fig. 34–40) of six species, characterized by the asymmetrical hypotheca with projecting sinistral lobe and broadly rounded epitheca. The series begins with *H. mediocre* (Plate 16, fig. 36) with only a slight sinistral lobe. There does not appear to be in the *pavillardi* series (Plate 16, fig. 26–33) of the subgenus Platydinium any indication of this lobe. The nearest approach to it elsewhere is seen in the rather divergent *H. scrippsi* (Plate 15, fig. 18) of the *rigdenae* series in the subgenus Heterodinium. *H. scrippsi* has an angular projection at the suture where the lobe develops in the *gesticulatum* series (Plate 16, fig. 34–40), and fuller shoulders on the epitheca than in any species in the subgenus Heterodinium. The postmargin of *H. scrippsi* is also asymmetrical and broadly angled as in *H. mediocre*. The two series in Platydinium are thus rather independent, except for the similarity in the epitheca.

The *gesticulatum* group (Plate 16, fig. 34–40) includes *H. mediocre, H. varicator, H. extremum, H. gesticulatum, H. scotti, H. deformatum,* and *H. sinistrum*. The first four form a series of increasing emergence of the sinistral lobe, and the last two are divergent, perhaps degenerate, types in which the right and left antapicals, respectively, are suppressed in development with compensatory adjustments in the shape of the epitheca and the shifting of the surviving antapical towards the median line.

Certain general tendencies appear in all of the seriated groups, as they have been arranged, as follows: (1) towards increase in volume; (2) towards increase in length; (3) towards development of apical and antapical horns; (4) towards increasing curvature of the horns; and (5) towards development of reticulations. Each series progresses from a small spherical, or more or less rotund type with less development of outgrowths and, in most cases, less reticulation, towards those with peripheral enlargements and differentiations.

Comparisons: — A near relationship of Heterodinium to Peridinium is suggested by the superficial resemblance of its species to those of that genus, especially of many species of the subgenus Heterodinium which have the same deep bifurcation into two antapical horns and tapering epitheca, for example in *H. blackmani*, as is found in *P. grande*. On this basis it would appear that Heterodinium is more nearly allied to Peridinium than to any other genus; but the thecal plates, especially on the epitheca, are of an entirely different type. Peridinium has its intercalary plates symmetrically placed middorsally, while in

Heterodinium the intercalary plate is always on the left shoulder. It is separated from Peridinium by many other well defined characters, such as the incompleteness of the girdle, the sculpturing, and the ventral pore, which is a much more constant and definite structure than it is even in *Gonyaulax*. Some species of Heterodinium such as *H. spiniferum* and *H. murrayi* approach some species of Gonyaulax, for example, *G. triacantha*, in superficial appearance, but the girdle and plate formula are quite different.

In many ways this is one of the more specialized and highly evolved genera in the *Peridinioidae*. Its extreme rarity of individuals, the delicate hyaline theca, the feeble development of chromatophores, the incompleteness of the girdle, suggest that degeneration has to some extent accompanied this specialization which may be correlated with the tendency of many of its species to live in the deeper, less illuminated levels of the tropical seas.

Heterodinium differs from Dolichodinium in lacking the anterior intercalary plate 1^a, in having 4 instead of 3 apicals, and in having 6 instead of 7 postcingulars.

Key to the subgenera of Heterodinium Kofoid

1. Body spheroidal or rotund; antapical horns absent or feebly developed as spines . . . . . Sphaerodinium.
1. Body elongated, flattened dorsoventrally with strong antapical horns 2
2. Epitheca narrowed towards the truncated apex . . . . . Heterodinium.
2. Epitheca expanded, scoop-like with rounded apex . . . . . Platydinium.

Subgenus Sphaerodinium Kofoid

Plate **13**; Plate **15**, fig. 1–10

Sphaerodinium Kofoid, 1906a, p. 350; Lindemann, 1928, p. 96.

The body is spheroidal or rotund, always circular at the girdle. Antapical horns, when present, are always small, in the form either of small spines or short hollow horns, less than 0.25 transdiameter in length.

Ten species (Plate **15**, fig. 1–10) are included in the subgenus: *H. kofoidi* Schiller (*non H. Kofoidi* Pavillard = *H. pavillardi* nom. sp. nov.), *H. sphaeroideum* Kofoid, *H. doma* Kofoid, and *H. calvum* Kofoid, constituting the *kofoidi* group; *H. minutum* Kofoid and Michener, *H. obesum* Kofoid, *H. murrayi* Kofoid, *H. milneri* (Murray and Whitting), *H. superbum* Kofoid, and *H. globosum* Kofoid, constituting the *minutum* group.

The type species is *H. sphaeroideum* Kofoid (1906a).

Key to the species of the subgenus Sphaerodinium Kofoid

1. Girdle without overlap ..... 2.
1. Girdle with overlap ..... 3.
2. Without antapical spines or horns ..... 4.
2. With antapical spines or horns ..... 5.
4. Distal end of girdle displaced posteriorly ..... 6.
4. Girdle horizontal, not distally displaced ..... *sphaeroideum* Kofoid.
6. Body small, length, 20μ ..... *kofoidi* Schiller.
6. Body larger, length, 70μ ..... 7.
7. Antapex rounded, postcingular rim not protuberant ..... *doma* (Murray & Whitting).
7. Antapex flattened, postcingular rim protuberant ..... *calvum* Kofoid.
5. Antapicals subequal ..... *superbum* Kofoid.
5. Antapicals very unequal ..... *globosum* Kofoid.
3. No apical horn, body globose, acicular spines ..... *minutum* Kofoid & Michener.
3. Apical horn more developed, spines finned ..... 8.
8. Apical horn well developed, 2 or 3 antapicals ..... 9.
8. Apical horn scarcely emergent, 4 antapicals ..... *milneri* (Murray & Whitting).
9. With 2 left antapicals on projecting lobe ..... *obesum* Kofoid.
9. With 1 left antapical and no lobe ..... *murrayi* Kofoid.

The *kofoidi* group

Plate 1, fig. 1–3, 8, 9; Plate 13; Plate 15, fig. 1–4

No apical horn, and no antapical spines or horns.

This group contains four species, *H. kofoidi* Schiller, *H. sphaeroideum* Kofoid, *H. doma* (Murray and Whitting) and *H. calvum* Kofoid. The last two only, occur in collections of the Expedition.

Heterodinium doma (Murray and Whitting)

Plate 1, fig. 8, 9; Plate 15, fig. 3

Peridinium doma Murray & Whitting, 1899, p. 327, pl. 30, fig. 3.
Heterodinium doma Kofoid, 1906a, p. 352.

Diagnosis: — A medium-sized, spheroidal species without horns or spines; length 1.07 transdiameters; epitheca flattened ventrally; hypotheca hemispherical with trace of flattening at the antapex; girdle wide, without posterior rim, furrow scarcely indented; surface reticulate, spinous. Length, 80 μ. Rare in the Eastern Tropical Pacific, in the Mexican Current, Easter Island Eddy, and South Equatorial Drift.

Description: — This is a medium-sized species, spherical except for a slight flare of the epitheca as it passes into the prominent precingular rim of the girdle, and for the flattening of the ventral face of the epitheca and a very slight flattening of the antapical region of the hypotheca. There is only a suggestion of

angularity in the outline of the body. The epitheca is a bit asymmetrical with its right shoulder thrown up apically and the left with a slight angle at the apical-precingular suture. The ventral face is flattened and the dorsal symmetrically rotund. The epitheca is a trifle larger than the hypotheca by about 0.5 girdle width. The apex, marked by the apical pore, is tilted ventrally about 10°.

The hypotheca is a little less than a hemisphere, flattened on the ventral face but not much excavated, and contracted distally a little more on the right than on the left side. The antapex in lateral view is broadly rounded and in the ventral somewhat flattened.

The girdle is submedian, wide, being 0.12 transdiameter across, has a very wide (0.6 its width) overhanging anterior rim, and only a trace of a posterior ridge. It is displaced distally its width. The furrow is only slightly and unevenly indented, more dorsally than ventrally.

The sulcus is very short, narrow, deep, and sinuous and it does not extend into the epitheca. Its total length is 0.25 transdiameter. The flagellar pore is large, irregularly circular.

The plates are normal, and sometimes separated by wide, smooth intercalary bands. The ventral pore is broadly reniform and its concavity is directed antero-dextrally. The surface of the plates is everywhere covered by a heavily marked, fairly regular reticulation except on the intercalary bands. There are about 25 polygons along the precingular ridge. Each polygon has a central pit and here and there the theca is spinose, along the suture lines, the spines arising at the junctions of the ridges forming the reticulation.

The cell contents were seen in only one individual in which they were collapsed in a granular mass less then 0.5 the transdiameter in longest diameter. In this mass there was a yellowish brown, ellipsoidal chromosphere, 0.35 transdiameter in longest diameter and a nucleus with minute moniliform granules. It was ellipsoidal and about 0.16 transdiameter in its longest axis.

Dimensions: — Length, 80 μ; diameter at the girdle, 78 μ. An individual figured by Murray and Whitting (1899) was only 58 μ long.

Comparisons: — The heavy reticulate and spinose surface markings distinguish this from all species of similar form in the subgenus Sphaerodinium. The angularity of the hypotheca is much less than in *H. calvum*, the apical pore is more deflected ventrally, and the ventral surface less deeply excavated than in that species. Since the spherical form is better preserved than in *H. calvum*, we regard it as less differentiated than that species, although the latter species has progressed further in surface markings.

Murray and Whitting's (1899, pl. 30, fig. 3) figure of this species resembles the specimens from the Expedition in the pattern and completeness of the reticulation, the general form of body, ventral suture, and location of ventral pore. It differs from those of the Expedition in smaller size (58 μ as compared with 80 μ), and in a more emergent postcingular ridge. One of our specimens (Plate **1**, fig. 8) has a slightly emergent ridge, but not as much as in their figure.

The type locality is 34°–39° N., 32°–39° W. in the Atlantic west of the Azores (Murray and Whitting, 1899).

Occurrence: — *Heterodinium doma* is recorded (Plate **13**) at five of the 127 stations. There are 1, 0, 0, 4, 0, and 0 stations on the six lines of the Expedition. Of these five stations, one (4590) is in the Mexican Current, three (4695, 4697, 4699) are in the Easter Island Eddy, and one (4701) is in the South Equatorial Drift. No specimens were taken in surface hauls. All five records are from hauls from 300–0 fathoms.

The temperature range of these five stations at the surface was 72°–83° and the average was 75.8°.

The frequency in all cases was less than 1%.

It was reported by Murray and Whitting (1899) from two stations in the warm temperate Atlantic between 34°–39° N. and 32°–39° W. in surface waters at 60°–66° in March.

In the Pacific all records but one (4590) in the Mexican Current are grouped in and near the Easter Island Eddy. In conjunction with the Atlantic records this species is eupelagic, confined to deeper levels, and rather widely eurythermal within tropical and warm temperate waters, though the evidence from the Expedition material by itself supports a restriction to warm-tropical deeper waters. The specimens from the two regions are so similar as to justify inclusion in one species.

Heterodinium calvum Kofoid

Plate **1**, fig. 1–3; Plate **15**, fig. 4

H. calvum Kofoid, 1907a, p. 177, pl. 7, fig. 43.

Diagnosis: — A medium-sized subspheroidal, somewhat angular species without horns or spines; length equals transdiameter; epitheca hemispherical; hypotheca with obliquely flattened antapex; furrow indented; surface smooth, porulate. Length, 75 μ. Rare in the Eastern Tropical Pacific, in the California Current, Easter Island Eddy, and the South Equatorial Drift.

Description: — In this rather small species the body is almost spheroidal; the length almost exactly equals each of the diameters at the girdle, which divides it equally. The epitheca is a low dome, flattened and excavated a little on its ventral face, evenly rounded at the apex, and with only a slight flare at the girdle. The ventral area is small with a large, reniform pore with the concavity facing right.

The hypotheca is rather angular; being excavated ventrally, a little compressed laterally, and obliquely flattened dorsoposteriorly.

The girdle is very wide and the furrow fairly deeply impressed (0.5 its width), with exceptionally well developed cingular ridges, the anterior one overhanging, and the posterior less developed than the anterior. Its postcingular rim is angled at the postcingular sutures on the dorsal side, but the precingular one is a continuous spiral. It is displaced its width or more.

The sulcus is a very narrow, deep groove and extends only a little way behind the posterior rim of the distal end of the girdle from which it is parted by plate 7″.

The plates are quite normal in arrangement. Postcingular 7″′ extends to the precingular ridge and lies at the right of the sulcus in the ventral trough. The spacing of the pores and traces of sutures in the furrow indicate seven girdle plates. The plates are marked in the hypotheca by the clearly defined ridges at the sutures, serrated around antapical 1″″ only. On the dorsal side of the epitheca the sutures are less distinctly ridged but are outlined by light bands. The thecal wall is sparsely and uniformly porulate, but has no surface reticulations. There are 32 pores across the dorsal precingular ridge and a single row in the furrow.

Dimensions: — Length, 75 μ; diameter at the girdle, 75 μ; girdle width, 10 μ.

Comparisons: — *Heterodinium calvum* is the largest species in the subgenus Sphaerodinium. It has developed the angles on the postmargin at points where antapical spines or horns emerge in the subgenus Heterodinium. It is distinguished from the other spheroidal and hornless species by this angularity of the postmargin of the hypotheca, a character which is less evident in *H. doma*. These two species are very much alike in form, but *H. calvum* differs from *H. doma* in the entire absence of reticulations and in the much greater development of the postcingular rim of the girdle, and greater angulation.

The type locality is Station 4691 in the Easter Island Eddy.

Occurrence: — *H. calvum* is recorded (Plate 13) at eight widely separated stations of the 127 stations. There are 1, 0, 0, 1, 1, 5, and 0 stations respectively on the six lines of the Expedition. Of these eight stations, one (4583) is in the

California Current, two (4691, 4695) are in the Easter Island Eddy, and five (4721, 4724, 4730, 4734, 4739) are in the South Equatorial Drift.

It was taken at one station only (4583) in a surface haul. All others are from hauls from 300–0 fathoms.

The temperature range at these eight stations at the surface was 72°–83°, and the average was 77°, a relatively high average.

The frequency at all the eight stations is less than 1%. This species has thus far not been found elsewhere.

It is a rare, eupelagic, stenothermal species of the Eastern Tropical Pacific, but is not limited to the deeper levels.

The *minutum* group

Plate **1**, fig. 4–7; Plate **2**; Plate **3**, fig. 1, 2, 4–6; Plate **4**; Plate **13**; Plate **15**, fig. 5–10

Apical horn more or less developed; antapical spines or horns present.

This group contains six species (Plate **15**, fig. 5–10), *Heterodinium minutum* Kofoid, *H. obesum* Kofoid, *H. murrayi* Kofoid, *H. milneri* (Murray and Whitting) *H. superbum* Kofoid, and *H. globosum* Kofoid, all of which occur in the collections of the Expedition.

Heterodinium minutum Kofoid and Michener

Plate **1**, fig. 4–7; Plate **15**, fig. 5

Heterodinium minutum Kofoid & Michener, 1911, p. 285.

Diagnosis: — A minute spheroidal species; length of body without spines 1.0 transdiameter, with premedian (at 0.3 total length) overlapping girdle, displaced 2 girdle widths; no postcingular list, furrow slight; two equal, oblique, acicular antapical spines and one similar ventral spine; surface smooth, sparsely porulate. Length, 40 μ. Rare in the Eastern Tropical Pacific in the Easter Island Eddy and South Equatorial Drift.

Description: — In this minute and rather unusual species the body is an almost perfect sphere, modified only by the precingular ridge and sulcal furrow. The epitheca is a flat dome of 0.4 transdiameter in altitude, flaring slightly in the precingular ridge at the girdle.

The hypotheca is large and rotund, 0.6–0.7 transdiameter long, with symmetrically rounded antapex. Below the sulcus is an excavation bounded by curved lateral ridges; the posterior end of each is continued into a short, acicular antapical spine, deflected ventrally 30° from the major axis and about 2 girdle widths in length. Further up on the left ridge at the end of the sulcus is a similar ventral spine.

The girdle is horizontal except in its displaced distal fourth. Its anterior rim is widely overlapping, but not curved downward. The postcingular rim is wholly lacking. The girdle is displaced 2.0 its width, being uniformly deflected in its distal quarter, and has an overlap of about its width. The furrow is but feebly impressed into the body wall, somewhat less distally than in its proximal region, and more distinctly anteriorly.

The sulcus is well developed, having a total length of 0.3 the length of the body. It is bounded by thickened ridges, raised into hyaline fins below the girdle, and continued on each side of the excavation towards the antapex. Below its posterior end a spreading, curved ventral excavation extends nearly to the antapex. Its distal width is 0.28 transdiameter.

No suture lines have been observed but the plating is indicated by the arrangement of the pores which are minute and few on each plate and only 12–13 across the dorsal side at the girdle. Faint reticulations mark the girdle plates and a short linear series runs down the right side of the posterior half of the sulcus. A low rim surrounds the apical and ventral pores. The latter is ellipsoidal and connected by a rib with the precingular rim.

The plasma is coarsely granular, and in one individual (Plate 1, fig. 7) a large, brown, spherical chromosphere was seen in the posterior end. Its spherical nucleus, 0.28 transdiameter in diameter, was centrally located. Highly refractive, spherical amyloid bodies smaller than the nucleus lay adjacent to the chromosphere and a very large pusule filled the left central region. The wall is noticeably thick.

Dimensions: — Length, 40 μ; transdiameter, 40 μ; antapical spines, 5 μ.

Variation: — One specimen from Station 4724 had no antapical spines though otherwise quite typical. The proportions and surface of the three specimens seen were uniformly similar.

Comparisons:—*Heterodinium minutum* is closely related to *H. sphaeroideum*, *H. kofoidi*, and other spheroidal species. This one differs in the possession of spines, in the overlapping and displaced girdle, as well as in the pattern of the thecal wall. It is a transition form between the *kofoidi* and *minutum* groups.

The type locality is Station 4697 in the Eastern Island Eddy.

Occurrence: — *Heterodinium minutum* was taken (Plate **13**) at only three of the 127 stations. There are 0, 0, 0, 2, 1, and 0 stations on the six lines of the Expedition. Of these three stations, one (4697) is in the Easter Island Eddy, and two (4701 and 4724) are in the South Equatorial Drift. All records are from hauls from 300–0 fathoms.

The frequency was always less than 1%.

The surface temperatures were 72°, 75°, and 79° respectively at the three stations.

This species is eupelagic in the Eastern Tropical Pacific and was not taken in surface collections.

Heterodinium obesum Kofoid

Plate **2**, fig. 4–6; Plate **15**, fig. 6

Heterodinium obesum Kofoid, 1907a, p. 183, pl. 8, fig. 50.

Diagnosis: — A minute obese species with globose midbody; its length, excluding spines, 1.2 transdiameters; short, prominent apical horn; two antapical spines with a large protuberance at the base of the left one; girdle overhanging, displaced 2.0 its width; surface sparsely and coarsely reticulate and porulate. Length, 55 (50–60) μ. Rare in the Eastern Tropical Pacific in the Panamic Area and the South Equatorial Drift.

Description: — This is a very small species with a rotund, obese body, 1.3 transdiameters in length, and circular at the girdle. The epitheca is a low cone of about 80° with concave sides laterally and ventrally, and convex locally dorsally. It is produced into a stout apical horn displaced ventrally from the major axis 0.18 transdiameter, making its total altitude 0.6 transdiameter. The apex is obliquely truncated, sloping ventrally. The horn is 0.5 the total altitude in length and is itself a truncated cone of 22°. A ventral area is scarcely defined but the pore is present as usual. It is ellipsoidal with the long axis subvertical and in line with the major axis. It is 0.33 of the altitude above the precingular ridge.

The hypotheca is larger than the epitheca, 0.8 transdiameter long, rotund, and with a rather deep ventral excavation. It is widest about the middle of the postcingular plates. The left side is protuberant below the girdle, the right is symmetrical, and the dorsal and ventral subhemispherical, but the ventral has a shorter radius than the dorsal.

The most striking development in this species is the prolongation of the body in a stout, left, antapical protuberance, so stout as to suggest the avoidance of the word "horn" as its designation. Morphologically it has the location of a left antapical horn, but structurally it is unlike the horn in any other species in the genus in that it is a broad, blunt process instead of a tapering one. It is a low subhemispherical dome, asymmetrically flattened, longer distally on the inner ventral region, and merging with the body more within a shorter distance dorsally than ventrally. Another reason for refraining from using the designation "horn" is the fact that it bears on its distal inner face a pair of antapical spines, the larger one of which is the homologue of the right spine. It is a rule in the genus for either spines or horns to be present when there are any antapical extensions. No other species has a spine on one side and a horn on the other.

The left antapical region has two oblique spines united by a common fin; the right has a single with a narrow fin.

The girdle is horizontal except in its distal fourth, which is so deflected posteriorly that its displacement is twice its width. There is considerable overlap at the ends, in fact nearly two girdle widths. The anterior rim is heavy, forming a sharp, projecting shelf which in one individual had a very low ribbed fin. The posterior rim is wholly wanting. The furrow also is completely lacking.

The sulcus is normal except for its great obliquity (45°), and is continued into the ventral excavation of the hypotheca which is also, by reason of the overhang of the girdle, much curved. It reaches the squarish postmargin where its width is 0.18 transdiameter.

The plates are normal. The left intercalary is rather large. Precingular 7 ″ is very narrow and crowded against the sulcus. The reticulations of the theca are imperfectly and unequally developed in all six specimens seen, being continuous only in the plates of the epitheca, postcingulars 1′ ″ and 2′ ″, antapical 2″ ″, and the girdle plates. The reticulations are relatively very coarse, about 16 across the dorsal side at the girdle. The wall is porulate, some polygons of the reticulum are without pores, many have one pore each, and the larger ones may have two or three. The suture lines are bordered by wide, smooth, hyaline bands of the intercalary type, especially on the epitheca.

Dimensions: — Length, 50 (55–60) μ; transdiameter, 40 μ; spines, 5 μ.

Variation: — One of our specimens taken at the same station (4734) as the one figured in Plate 2, figures 4–6, had a wider girdle, with a slight furrow and a more tapering antapical prolongation with the reticulations much less developed,

except in the girdle region. A specimen from Station 4638 had an apical horn proportionately 25% longer than the one figured on Plate 2.

Comparisons:—This species is marked off from all others in the genus by the posterior prolongation. It otherwise has marked resemblances to *H. globosum* and *H. murrayi*. *H. minutum* and *H. milneri* share with this species the displaced overhanging girdle.

The type locality is Station 4734 in the South Equatorial Drift.

Occurrence: — *Heterodinium obesum* is recorded (Plate 13) at six of the 127 stations with a total of seven specimens. There were 0, 0, 2, 1, 3, and 0 record stations respectively, on the six lines of the Expedition. Of these six stations, one (4638) is in the Panamic Area and the other five (4681, 4701, 4730, 4732, 4734) are in the South Equatorial Drift. They were taken only in hauls from 300–0 fathoms, except for one at Station 4681 from 800–0 fathoms.

At Station 4681 the frequency reached 1%. At this, and all other stations, single specimens only were found, except at Station 4734, where two were ultimately discovered.

The temperature range of these five stations at the surface was from 68° to 84° and the average was 76.7° F.

Its absence from the Peruvian Current and from surface collections is alike noteworthy. The limited data suggest a stenothermal limitation of this eupelagic species to the deeper waters of the tropical currents.

Heterodinium murrayi Kofoid

Plate 2, fig. 1–3; Plate 3, fig. 3; Plate 15, fig. 7

Peridinium tripos Murray & Whitting, 1899, p. 327, pl. 30, fig. 4a, b; Ostenfeld & Paulsen, 1904, p. 167.
non *Peridinium tripos* Ehrenberg, 1834, p. 272.
Heterodinium murrayi Kofoid, 1906a, p. 343, 353.

Diagnosis: — A minute, top-shaped, symmetrical species, length, excluding spines, 1.16 transdiameters, with a short, stout apical horn; hypotheca hemispherical, with 3 aciculate spines; girdle overhanging, displaced 2.0 its width; surface fully reticulated. Length, 58 μ. Rare in the tropical Atlantic and in the Mexican and Peruvian Currents and the South Equatorial Drift of the Pacific.

Description: — In this small species the body apart from the apical horn is very rotund, but this structure gives it the form of a stout top. It is circular at the girdle which divides the midbody subequally. Its total length is 1.2 trans-

diameters. The epitheca is conical (70°) and drawn out into a stout, asymmetrically conical (30°) horn, squarely truncated at the apex, 0.2 transdiameter long, tilted to the left slightly, and more concave dorsally than ventrally. The right outline is sigmoid, the left straight to concave. The ventral area is a subtriangular hyaline region just above the proximal end of the girdle, irregularly shaped, with the pore near the anterior end. The ventral pore is broadly ellipsoidal and quite minute.

The hypotheca is subhemispherical, slightly inflated to the right. The postmargin is broadly rounded and bears three aciculate, finned spines, 0.2 transdiameter long, two of them symmetrically placed 0.35 transdiameter apart on the antapex, and the third ventrally and to the left some distance from the edge of the postsulcal excavation.

The girdle is median, horizontal in dorsal view, and displaced 2.0 its width with an overlap of a girdle width. The furrow is not impressed but the precingular rim forms a steeply overhanging shelf with arched lower surface. The posterior rim is wanting entirely.

The sulcus is normal, 0.43 of the transdiameter in length, with a slight sigmoid curve, tilted to the right 20° from the axis and guarded by a low sinistral list. The postsulcal excavation is not differentiated.

The plates conform closely to type; the anterior intercalary (Plate 3, fig. 3) is a quadrilateral and posteingular 7″ ′ laterally expanded. The suture lines are in some places marked by rows of small polygonal reticulations, and elsewhere by hyaline, plain intercalary zones between the coarse-meshed markings which cover the body generally including the girdle. There are 18 polygons across the dorsal side at the girdle. Generally there is a single pore in the center of each polygon.

The plasma is finely granular. In one specimen there were three brownish chromospheres which stain deeply in Ehrlich's haematoxylin. The nucleus is subcentral, ellipsoidal, 0.16 transdiameter in longest diameter and resists staining (fixed in formalin) in the Ehrlich's stain. In this specimen (Plate 2, fig. 3) there was a cluster of fine filamentous rhabdosomes in the apical plasma and in the space between theca and plasma. Some of them were escaping with plasma through the apical pore.

Dimensions: — Length, 58 μ; diameter, 48 μ; major antapical spines, 10 μ.

Variation: — The individual figured by Murray and Whitting (1899) has the apical horn and the spines much shorter than in our material. The reticulation is much more heavily marked, and the overhang of the girdle is a little

greater, and the postsulcal excavation more marked. These differences may be more than mere intraspecific variations. However, they occur in well known variable features and there is a sufficient similarity between their figure and ours in girdle, spines, and general habitus, so that we hesitate to regard our material as specifically distinct from theirs.

Comparisons: — This is a species of the same type as *H. obesum* but has more development of apical horn and surface markings. It differs from *H. milneri* in being less rotund, in having longer apical and antapicals, and also in more numerous, smaller reticulations. From the higher members of the series, *H. superbum* and *H. globosum*, it differs notably in having finned, aciculate antapical spines, instead of hollow antapical horns formed as extensions of the theca and its cavity.

Synonymy: — This species was first described by Murray and Whitting (1899) as *Peridinium tripos*. This specific name is preoccupied in Peridinium by *P. tripos* Ehrenberg (1834). Kofoid (1906a) therefore replaced it by *murrayi* and transferred the species to his new genus Heterodinium. Schiller (1916, p. 209) restores the specific name *tripos* in Heterodinium for Murray and Whitting's species but without stating the grounds.

The type locality is 14°–31° N., 38°–58° W. in the Atlantic (Murray and Whitting, 1899).

Occurrence: — *Heterodinium murrayi* is recorded (Plate **13**) at six very widely scattered stations of the 127 stations of the Expedition. There were 1, 2, 1, 0, 2 and 0 stations respectively on the six lines of the Expedition. Of these six, one (4594) is in the Mexican Current, two (4667, 4670) are in the Peruvian, and three (4679, 4722, 4724) are in the South Equatorial Drift. At Station 4670 it was taken in a haul from 800–0 fathoms, elsewhere only in hauls from 300–0 fathoms.

It is very rare, the frequency always being less than 1%.

The temperature range at these six stations at the surface was from 68°–84°, and the average was 73.6°.

Murray and Whitting (1899) record the species from the tropical Atlantic between 14° and 31° N. and 38° and 58° W. at four different stations in March and April from surface collections at 67° and 78°. Ostenfeld and Paulsen (1904, p. 167) report it as "*Peridinium tripos* Murray and Whitting" as very rare in the North Atlantic at 59° N. 16° W. in surface temperature of 48° F. These records indicate a northward extension in Gulf Stream water.

This species is eupelagic and eurythermal. It evidently has a wide distribution, is either more abundant or occurs more freely near the surface than most of

the species in the genus, and has a more northerly range. It was, however, not found in the colder Peruvian Current in the collections of the Expedition, an additional reason for the suspicion that the form from the Eastern Tropical Pacific may be specifically distinct from that in the Atlantic. The matter can be decided when more material from the Atlantic can be examined.

Heterodinium milneri (Murray and Whitting)

Plate 3, fig. 1, 2, 4–6; Plate 15, fig. 8

Peridinium milneri Murray & Whitting, 1899, p. 327, pl. 29, fig. 3a, b.
Heterodinium milneri Kofoid, 1906a, p. 353.

Diagnosis: — A stout subspheroidal species, with a low, stout apical horn and four stout, finned antapical spines; girdle displaced 2.0 its width with 2 girdle widths overhang; theca very coarsely reticulated. Length, 65 μ. Rare in the tropical Atlantic and Pacific in the Mexican and Peruvian Currents and the South Equatorial Drift.

Description: — This is a small, very stout, subspheroidal species, subcircular in section at the girdle, length including the spines 1.22 transdiameters, with epitheca and hypotheca subequal. The epitheca is dome shaped, a low cone of 100° with almost straight sides in dorsal or ventral view, except towards the apex which is drawn out into a low stout horn with a cupped apical pore. The ventral face is slightly concave and the dorsal slope is 1.35 greater than the ventral.

The hypotheca is more rotund, with evenly rounded antapex except when tilted ventrally. The antapical region has a ventral tilt which deflects the antapical spines about 20° from the axis of the hypotheca as a whole. Because of the absence of the postcingular ridge, the hypotheca appears to exceed the epitheca, but, if the girdle plates are excluded, their equality is more evident. It bears the four stout antapical spines each a girdle width long. The right accessory is small in our specimen (Plate 3, fig. 4). The relations of these spines are not clearly shown in Murray and Whitting's (1899, pl. 29, fig. 3b) figure. There are two proximal, more dorsally located spines, the homologues of the two antapicals in *H. minutum*, and two slightly smaller, more ventrolaterally placed, accessory spines.

The girdle is premedian in its proximal 0.25, median dorsally, and slightly postmedian in its distal 0.25. It forms a descending spiral, displaced 2.0 its width, with an overlap of at least 2 girdle widths. The precingular ridge is prominent, the postcingular wholly undeveloped. The precingular ridge is

relatively low, less than 0.5 girdle width wide, is almost horizontal below, and has a very narrow ribbed list.

The sulcus is a deep, sinuous groove with thickened edges forming a sigmoid curve with enlarged ends, 0.4 of the total length, without a distinct postsulcal trough.

The anterior intercalary plate is peculiar in being very small and marked only by two tiny pores or pits (Plate 3, fig. 2, 4).

The thecal wall has a very coarse reticulation of polygons, each with a central pit, which fills the central area of each plate, being absent in the wide smooth intercalary border along the suture lines. The thickenings forming the pattern are continued as short ribs on the precingular ridge. The ventral pore in the epitheca is located unusually far anterior, at the base of the small apical horn. It is but little larger than the pores in the adjacent polygons.

The cell contents of one specimen (Plate 3, fig. 1) consisted of a finely granular cytoplasm crowded with hyaline, radially arranged, homogeneous, stout, rod-like bodies of unknown nature. There were seven spheroidal or ellipsoidal chromospheres of various sizes clustered in the center and an ellipsoidal nucleus with moniliform chromatin threads.

Dimensions: — Length, 65 μ; transdiameter, 55 μ; spines 8 μ.

Comparisons: — *Heterodinium milneri* shares many characters with *H. murrayi*, the rotund midbody, the displaced overhanging girdle, and the presence of finned spines. But the apical horn is here less developed and there are four instead of three antapical spines, the surface markings of *H. murrayi* form a complete network over the whole surface, and its antapical spines are longer and more slender. Furthermore the apical pore is much farther anterior in *H. milneri* than in *H. murrayi*.

Synonomy: — Murray and Whitting (1899) described this as *Peridinium milneri* and Kofoid (1906a) transferred it to Heterodinium.

The type locality is 29°–31° N., 42°–44° W., in the Sargasso Sea (Murray and Whitting, 1899).

Occurrence: — *Heterodinium milneri* (Plate 13) is recorded at nineteen of the 127 stations. There are 1, 0, 8, 5, 4, and 1 station respectively on the six lines of the Expedition. Of these nineteen stations, one (4583) is in the Mexican Current, one (4676) in the Peruvian Current, fifteen (4679, 4680, 4681, 4683, 4685, 4686, 4689, 4705, 4707, 4711, 4722, 4724, 4732, 4734, 4740) are in the South Equatorial Drift, and two (4697, 4699) are in the Easter Island Eddy. At only three stations (4583, 4680, 4686) is the species recorded in surface collections.

All other records are from 300–0 fathoms except those at 4681 and 4689 which are from 800–0 fathoms only. There is also a record at 800–0 fathoms at Station 4724.

The temperature range was 68°–83° and the average 74.1°.

The frequency was 1% or less at all record stations, a total of 20 specimens having been seen.

The aggregation of 17 of the 19 record stations in the South Equatorial Drift (15) and adjacent Easter Island Eddy (2), the presence of only a single record in the Peruvian Current, and its absence from the Panamic Area, is indicative that this is a tropical species with its center of distribution in the large central area of the Eastern Tropical Pacific occupied by the South Equatorial Drift. In frequency of record (19) it is approached in the genus only by *H. curvatum* (17) and *H. gesticulatum* (16), and surpassed only by *H. rigdenae* (23), all of which have their centers of record in the South Equatorial Drift along with *H. milneri*, but unlike it, both *H. rigdenae* and *H. gesticulatum* occur also in the cooler Peruvian Current and Panamic Area more widely, and are to this degree less typically tropical than *H. milneri*.

Murray and Whitting (1899) reported this species from the tropical Atlantic between 29° and 31° N. and 42° to 44° W. at eleven record stations in November, December, and March, in temperatures of 67° to 81°.

This species is eupelagic, eubathmic and stenothermal, with a limitation to the warmer tropical seas, and is only occasionally taken in surface waters, three times by this Expedition and four times by Murray and Whitting. It is rare, though widely distributed.

Heterodinium superbum Kofoid

Plate **4**, fig. 5–7; Plate **15**, fig. 9

Heterodinium superbum Kofoid, 1907a, p. 185, pl. 8, fig. 49.

Diagnosis: — A small species of robust habit; with dorsoventrally flattened apical horn scarcely developed; hypotheca angular; small, subequal, acute, antapical horns; girdle 0.12 transdiameter in width, displaced its width but no overhang, with very low postcingular rim; sulcus nearly straight; surface reticulate throughout. Length, 75 μ. Rare in the Eastern Tropical Pacific in the Easter Island Eddy.

Description: — This is a small robust species, subglobose and but slightly elongated, its length 1.3 the transdiameter, 1.4 the dorsoventral, divided equally

by the girdle. The epitheca is subconical (80°–90°), dorsoventrally compressed towards the truncated apex and flaring slightly at the girdle. Its outlines are convex except distally on all faces. There is only an indication of an apical horn, except in lateral view (Plate 4, fig. 6) in which it is asymmetrically conical (30°) and less than a girdle width in length with squarely truncate apex. The ventral area is a small rectangle displaced to the left with a reniform pit or ventral pore at the center with the concavity at the right.

The more rotund hypotheca is rather angular at the postcingular and antapical sutures. Its ventral face is flattened and excavated, its dorsal side broadly rounded and flattened dorsal to the ventrally deflected antapical horns.

There are two short, stout, conical antapical horns, acutely pointed, the left stouter (35°) than the right (25°), and a girdle width in length. The right horn is a bit the shorter. They are deflected ventrally 25° from the vertical axis of the body. They are hollow extensions of the body, not solid spines as in *H. milneri*.

The girdle is very wide, 0.12 transdiameter in width, median in location, and displaced distally its width. Its precingular rim is heavy and overhanging with a very narrow ribbed list on its edge. The lower surface of this ledge is flattened, rather than curved, with its slope exposed to view. The postcingular ridge is developed as a slightly protuberant angle marked by a row of small reticulations. The ends of the girdle scarcely meet, overhang being wholly absent. The furrow is indented as an angular trough nearer the precingular than the postcingular rim.

The sulcus is quite straight, almost vertical, and very narrow except for a small expansion at the proximal end of the girdle where the flagellar pore opens. A low list borders the right side of the posterior sulcus below the pore. There is a wide straight, very deep, postsulcal trough, 0.25 transdiameter in width, with a convex postmargin between the antapical horns.

The plates are normal. The anterior intercalary 1^a is very large and is extended almost to the apex. Postcingular $7''$ is long and narrow and crowded into the ventral excavation. Strong, ridged suture lines separate the plates. The lines on the hypotheca contain a row of small quadrilateral reticulations. The surface generally is uniformly and rather coarsely reticulate. Each polygon has a small pore at the center. A double row of quadrilateral polygons fills the entire girdle.

Dimensions: — Length, 75 μ; transdiameter, 60 μ; dorsoventral diameter, 56 μ; length of left antapical horn, 12 μ.

Comparisons: — This species is the first of the *minutum* series to have antapi-

cal horns instead of spines. The shape of body is more rotund posteriorly than in *H. milneri*. In this respect it closely resembles *H. globosum*, but differs in the well developed surface markings and in the slight emergence of a definite apical horn. Its antapicals are also more nearly equal. In some characters, such as the flattening of the apical region, the bifurcated form of the antapex, and development of reticulations, it approaches the subgenus Heterodinium, but on account of its globose body, it belongs more naturally to the subgenus Sphaerodinium.

The type locality is Station 4699 in the Easter Island Eddy.

Occurrenee: — There is only a single record (Plate **13**) of *Heterodinium superbum* at Station 4699 on the fourth line of the Expedition, in the Easter Island Eddy in a haul from 300–0 fathoms. The surface temperature there was 75° F. Only a single specimen has been seen.

Heterodinium globosum Kofoid

Plate **4**, fig. 1–4; Plate **15**, fig. 10

Heterodinium globosum Kofoid, 1907a, p. 181, pl. 8, fig. 51.

Diagnosis: — A large species with a globose midbody; length 1.5 transdiameters, small apical horn; stout unequal antapical horns and asymmetrical postmargin; surface incompletely and very irregularly reticulated. Length, 110 (100–120) μ. Rare but widely distributed in the Eastern Tropical Pacific in the Mexican and Peruvian Currents, Easter Island Eddy, and South Equatorial Drift.

Description: — The body of this rather large, rotund species is, apart from the horns and sulcal depression, spheroidal, or slightly elongated, and divided equally by the girdle. Its length is 1.45 transdiameters. The epitheca is broadly campanulate, with hemispherical base with flaring rim. It is produced into a short, stout, asymmetrically conical (40°) apical horn with obliquely truncated apex drawn out in a point in the dextroventral quadrant, which increases its total altitude to 0.7 transdiameter. It flares abruptly at the girdle in the precingular rim and has only an indication of ventral flattening. A ventral area is not defined in the surface markings but the usual ventral pore is present. It lies as usual at the junction of the apical-precingular suture with the midventral suture which is very considerably deflected to the left. It is broadly ellipsoidal with its long axis in the oblique suture line.

The hypotheca is more perfectly hemispherical than the epitheca except for the deep ventral excavation and the two horns.

It bears the two short, stout, sharply pointed, unequal antapical horns. Both are tilted ventrally about 30° and the tip of the left is curved ventrally. The left is about 0.25 transdiameter long, and the right but half as much or less, and somewhat more laterally deflected. The postmargin is asymmetrically concave and the distance between the bases of the horns is 0.35 transdiameter.

The sulcus is relatively smaller than in most species, slightly expanded about the flagellar pore, and guarded laterally on each side by a low, hyaline list. Its length is 0.3 transdiameter and the postsulcal trough is lost in the general ventral excavation of the hypotheca. The surface is marked here and there by a very irregular mesh work consisting of incompletely developed reticulations, some large and marked with a central pit, some very small without a pit. The suture lines are bounded by very wide, smooth intercalary bands. The locations and pattern of the developing reticulations are noteworthy. In all specimens seen the mesh is only in the earliest phase of emergence. It is uniformly best developed on the ventral face and nearest the flagellar pore, in the girdle, on the ventral pre- and postcingular plates, and especially on precingular 1″. The mesh on the left side is better developed than on the right, and on the left horn more than on the right. The mesh starts about the periphery of each plate marking off the intercalary zone and the polygons converge centripetally from this marginal ridge. Small pitless polygons spread centrifugally from the marginal ribs into the intercalary zones.

The cell contents in one individual observed in life consisted of fine homogeneous, very hyaline cytoplasm containing a large spheroidal, pale yellowish green chromosphere, 0.5 transdiameter in diameter, and centrally located. At its left was an ellipsoidal nucleus whose long diameter was 0.35 transdiameter containing finely beaded chromatin (chromosomes). A large number of small, subuniform oil droplets covered the anterior surface of the chromosphere. No pusule was seen. A specimen stained in haematoxylin revealed finely granular cytoplasm, no pusule, the nucleus and deeply stained chromosphere located as in life, and, in addition, a bundle of subparallel, acicular rhabdosomes in the cytoplasm near the flagellar pore and two other stained bodies, possibly accessory chromospheres adjacent to the major chromosphere. The whole cell is unusually hyaline in life.

Dimensions: — Length, 110 (100–120) μ; transdiameter, 85 μ; right antapical, 14–22 μ, and left, 3–6 μ.

Comparisons: — This species shares with *H. superbum* the presence of antapical horns, but differs from it in incomplete reticulations and lack of angularity.

In shape it is nearly related to *H. obesum;* the two are remarkably similar in form and surface markings, but *H. obesum* has antapical spines instead of horns, is much larger, while *H. globosum* lacks entirely the characteristic antapical protuberance and overhang and displacement of the girdle of *H. obesum.*

The type locality is Station 4699 in the Easter Island Eddy.

Occurrence: — *Heterodinium globosum* is recorded (Plate **13**) at fourteen of the 127 stations with a total of 14 specimens seen. There are 3, 0, 5, 3, 2, and 1 stations respectively on the six lines of the Expedition. Of these fourteen stations, three (4587, 4590, 4604) are in the Mexican Current, one (4676) in the Peruvian Current, seven (4679, 4689, 4691, 4701, 4724, 4737, 4740) in the South Equatorial Drift, and three (4692, 4697, 4699) in the Easter Island Eddy. The species was taken at only three stations (4590, 4604, 4692) in surface hauls. It was taken once (Station 4587) in a haul from 100–0 fathoms and once (Station 4689) from 800–0 fathoms, all other records being from 300–0 fathoms.

The temperature range at the fourteen stations was 69°–84° and the average 76.5°.

Only at two adjacent stations (4691, 4692) is the frequency 1%, at the other twelve it is less.

This species is the largest in the *minutum* group, and in part for this reason is retained more readily by the mesh of the silk net. It is surpassed in frequency by *H. milneri* (19 records) in the *minutum* group, and by *H. curvatum* (17), *H. fenestratum* (15), *H. gesticulatum* (16), and *H. rigdenae* (23) in the rest of the genus. Its absence in the Panamic Area, the single record in the Peruvian Current, and the high average temperature (76.5°), all indicate a stenothermal limitation to warm tropical waters. It has a marked center of occurrence in the South Equatorial Drift and is typically eupelagic with a preference for deeper waters.

Subgenus Heterodinium nom. subgen. nov.

Plate **15**, fig. 11–25

Euheterodinium Kofoid, 1906, p. 351; Lindemann, 1928, p. 96.

The body is more or less elongated and flattened dorsoventrally. The epitheca narrows towards the truncated apex and sometimes has a well defined apical horn, the hypotheca is bifurcated into large, subequal antapical horns giving a superficial resemblance to the genus Peridinium. Type species *Heterodinium scrippsi* Kofoid (1906a).

This subgenus consists of three groups, the *expansum* group with contracted apical horn; the *dispar* group with no lateral contraction in the apical region into a distinct horn in ventral view and with elongated epitheca and antapicals, and the *rigdenae* group with shorter epitheca and antapicals.

Key to the species of the subgenus Heterodinium

1. With apical horn set off from epitheca in ventral view . . 2.
1. Apical horn not set off, epitheca conical in ventral view . . 3.
2. Large species, length 240 μ, midventral suture very abruptly angled . *praetextum* Kofoid.
2. Smaller species, midventral suture nearly straight and vertical . . 4.
4. Lateral outlines of epitheca abruptly angled . . *angulatum* Kofoid and Michener.
4. Lateral outlines without abrupt angles . . 5.
5. Epitheca broadly and equally convex laterally, antapicals subvertical . *expansum* Kofoid.
5. Epitheca unequal laterally, the right side slightly convex, the left less or concave . 6.
6. Antapicals slender, tapering, spreading . . *spiniferum* Kofoid and Michener.
6. Antapicals stout, incurved distally . . *fenestratum* Kofoid.
3. Lateral margins of epitheca with angled shoulders, antapicals spreading unequally . *scrippsi* Kofoid
3. Lateral margins of epitheca not angled, generally straight or concave . 7.
7. With three antapicals, two on the left . . *trirostre* (Murray and Whitting).
7. With two antapicals . . 8.
8. Antapicals quite unequal . 9.
8. Antapicals equal or subequal . 10.
9. Completely reticulated, suture between 1′ and 1″ very oblique . *crassipes* Schiller.
9. Partly reticulated, suture between 1′ and 1″ horizontal . 11.
11. No spinules on distal end of antapicals . *dispar* sp. nov.
11. With spinules on distal end of antapicals . *leiorhynchum* (Murray and Whitting).
10. Antapicals not incurved distally . 12.
10. Antapicals incurved distally . 13.
12. Antapicals subvertical, distance between tips not over two girdle widths *elongatum* Kofoid and Michener.
12. Antapicals spreading, distance between tips over three girdle widths . *rigdenae* Kofoid.
13. Antapicals tapering, slender . *blackmani* (Murray and Whitting).
13. Antapicals stout, abruptly pointed . 14.
14. Length, 118–128 μ . *hindmarchii* (Murray and Whitting).
14. Length, 200–235 μ . *curvatum* Kofoid.

The *expansum* group

Plate 5, fig. 5–7; Plates 6, 7, 13; Plate 15, fig. 11–15

The epitheca is contracted into a distinct apical horn. Antapical horns tend to be equal.

This group contains five species, *H. expansum* Kofoid, *H. angulatum* Kofoid and Michener, *H. spiniferum* Kofoid and Michener, *H. fenestratum* Kofoid, and *H. praetextum* Kofoid, all described from the collections of the Expedition.

Heterodinium expansum Kofoid

Plate 5, fig. 5–7; Plate 15, fig. 11

H. expansum Kofoid, 1907a, p. 178, pl. 6, fig. 36.

Diagnosis: — A medium-sized, stout species, much flattened dorsoventrally; dorsoventral diameter, 0.35 transdiameter; length, 1.3 transdiameters; apical horn small, with rounded apex, tilted ventrally; antapical horns short, slender, acute, widely set, straight; girdle very oblique (40°) not overhanging; surface completely and irregularly reticulated. Length, 117 (110–130) μ. Rare in the Eastern Tropical Pacific in the Panamic Area, Peruvian Current, and South Equatorial Drift.

Description: — This is a medium-sized species with a body almost circular in outline in ventral view, except for horns and girdle, and strongly flattened dorsoventrally, the transdiameter being about 3.0 the dorsoventral. The epitheca and hypotheca are about equal and both apex and antapex are tilted ventrally. The epitheca has a broadly rounded outline in the ventral view with high shoulders. It exceeds a semicircle in ventral view and is less in dorsal. It forms 0.56 of the total length in ventral view and 0.35 in the dorsal. It is drawn out abruptly into a short, conical (40°) apical horn, tilted ventrally almost 40°, and nearly vertical to the plane of the girdle. It is nearly two girdle widths long with rounded apex and small, horizontally truncate apical pore. The ventral area is an elongated, vertical, smooth tract, two girdle widths in length midway between girdle and apical pore. The ventral pore is broadly reniform with the concavity facing anterodextrally. It is located at the anterior end of the ventral area.

The broad hypotheca is a little narrower than the epitheca, with its outline less evenly rounded. Its lateral outline, owing to the spreading antapicals, forms sigmoid curves. Its dorsal face is flat and the ventral concave and deeply excavated.

The two stout, conical, finned antapical horns are wide-set, divergent not over 18°, each about 2.0–2.5 girdle widths in length, and with acute or slightly blunt ends. The right is a trifle stouter and a bit shorter than the left. The postmargin between them is horizontal and almost straight with a toothed edge.

The very oblique (40°) girdle is displaced distally its own width. It is unusually narrow, being only 0.12 transdiameter wide on the ventral face and wider dorsally. The precingular ridge scarcely flares from the epitheca. It lower surface is angled rather than arched. The furrow is not impressed and there is only a faint trace of rise at the postcingular margin. There is no overhang.

The sulcus is much reduced, being very narrow, and ending a girdle width below the postcingular edge. It is vertical, straight, without lists, and has only a slight expansion at the pore. A broad postsulcal trough is deeply excavated below it with a postmargin 0.38 transdiameter wide.

The plates are normal. The anterior intercalary 1^a lies low on the left shoulder, its upper margin being scarcely half way to the apex. Postcingular $7'''$ is short, broad, and smooth. The entire surface is closely, completely, and rather uniformly reticulate, the polygons being larger in the girdle and on the dorsal side of the hypotheca. The only smooth surfaces are the ventral area, postcingular $7'''$, and, in one specimen, the intercalary zones. A secondary, finer, more porulate mesh occurred around the periphery of the plates next to the intercalary zone in one specimen. There are 25 polygons across the dorsal face along the precingular rim.

In an individual observed alive, the plasma was very hyaline, and did not fill the theca. The nucleus was ellipsoidal and centrally placed. Minute chromatophores of a very pale yellowish green color were irregularly distributed on the right side of the body.

Dimensions: — Length, 117 (110–130) μ; transdiameter, 93 (85–100) μ; dorsoventral diameter, 27 μ; antapical horns, 16 μ.

Comparisons: — *Heterodinium expansum* finds its nearest relative in *H. angulatum;* except for the flattening of the body and rounded shoulders in contrast to the rotundity and squarish shoulders of the latter, the two species are somewhat alike.

The type locality is Station 4637 in the South Equatorial Drift.

Occurrence: — *Heterodinium expansum* is recorded (Plate **13**) at only three of the 127 stations. There are 0, 1, 2, 0, 0 and 0 stations on the six lines of the Expedition. Of these three stations, one (4637) is in the Panamic Area, one (4713) in the area assigned to the Galapagos Eddy, and one (4701) in the South Equatorial Drift. All three were in hauls from 300–0 fathoms with only a single specimen in each haul.

The temperature at the surface ranged from 72° to 76° and averaged 73.7°.

This species is rare, eupelagic, and seemingly stenothermal in the cooler tropical regions in deeper levels.

Heterodinium angulatum Kofoid and Michener

Plate 6, fig. 1, 2; Plate 15, fig. 12

Heterodinium angulatum Kofoid & Michener, 1911, p. 284.

Diagnosis: — A small stout species; length, 1.3 transdiameters, with short apical horn arising abruptly from the angular shoulders of the epitheca; antapical horns equal, tapering, bluntish, incurved and ventrally deflected; postcingular rim wholly undeveloped; surface coarsely and unevenly reticulated. Length, 85 μ. Rare in the Eastern Tropical Pacific in the Easter Island Eddy.

Description: — In this robust species the body is very angular in ventral view, elongated to a length of 1.3 transdiameters, and obese dorsally in lateral view. The midbody is globose, scarcely compressed, but excavated midventrally, the dorsoventral diameter being 0.9 the transverse. The antapex is tilted ventrally nearly 45° from the axis of the epitheca. The epitheca flares widely at the girdle and has abruptly squared shoulders in ventral view above which it is drawn out into a short, conical (30°) apical horn, 0.3 of its height with squarely truncate apical pore. In lateral view it has the outline of a cone of about 80°. The altitude of the epitheca is 0.7, and of the horn 0.35 transdiameter, and in lateral view the lower part is a cone of 90° with some midventral excavation.

The hypotheca is of about the same size as the epitheca, rather less angular dorsally; it narrows only slightly towards the antapex. Its length to the tip of the horns is 0.8, and to the middle of the postmargin, 0.5 transdiameter.

It bears two equal, tapering, incurved, conical (25°) horns, stout, and rather bluntly pointed, with a subsemicircular, serrated postmargin between them. Their length is 0.25 the transdiameter and the distance between their tips is 0.55 transdiameter.

The girdle is median, very wide, with strong, overhanging precingular rim, arched beneath. There is no trace of the postcingular ridge. Its distal end is displaced posteriorly about 0.5 girdle width. The sulcus and ventral face are unknown.

The plates are separated by narrow intercalary bands covered with a minute nonporulate reticulation. The entire surface except in the part of the intercalary zones is heavily and coarsely reticulated with a pattern of fairly regular polygons each with a central pore across the dorsal side of the epitheca, and 15 at the postmargin of the precingular plate. The intercalary plate 1^a had dropped out of the wall in our specimen. It lies about midway between apex and girdle on the dorsal face.

The plasma is coarsely vacuolated, the nucleus spherical, about 0.3 transdiameter across, and located at the left of the major axis at the girdle level. Nothing else is known of the living cell.

Dimensions: — Length, 85 μ; transdiameter, 60 μ; dorsoventral diameter, 55 μ; length of antapical horns, 15 μ.

Comparisons: — *Heterodinium angulatum* forms a bridge between the subgenera Heterodinium and Sphaerodinium. It has the globose body, little compressed, of the latter, but the form of the body in a ventral view so much recalls that of a typical Heterodinium that it is placed in that subgenus. It serves to show that the distinction between the two groups is not a sharp one.

The type locality is Station 4691 in the Easter Island Eddy.

Occurrence: — *Heterodinium angulatum* is one of the rarest species of the genus, being reported (Plate **13**) only at Station 4691 in the third line in the Easter Island Eddy in a haul from 300–0 fathoms at the surface temperature of 73° F. It is eupelagic from the deeper levels in tropical seas.

Heterodinium spiniferum Kofoid and Michener

Plate **6**, fig. 4–6; Plate **15**, fig. 13

Heterodinium spiniferum Kofoid & Michener, 1911, p. 286.

Diagnosis: — A small species; length, 1.3 transdiameters, with tapering apical horn and long, slender, spinulate antapical horns; precingular rim widely overarching, the postcingular wholly wanting in the distal 0.25, feebly developed elsewhere, girdle not overhanging; surface coarsely reticulate. Length, 85 μ. Rare in the Eastern Tropical Pacific in the Easter Island Eddy.

Description: — In this rather peculiar species there is a wide midbody, only slightly compressed at the girdle, but drawn out into very long apical and antapical horns, all slightly inclined ventrally. The total length is 1.3 transdiameters, 1.8 the dorsoventral. The epitheca is nearly a girdle width longer than the hypotheca, and has rounded shoulders, fuller and somewhat angled on the right side, and concave with median swelling on the left. Both dorsal and ventral faces are concave, the latter more than the former. The epitheca is drawn out into a tall slender horn, straight in lateral view, conical (20°) in ventral, almost 0.5 transdiameter in length, and with a truncated apex with a dorsally enlarged lip. The ventral area is much elongated, 0.3 of the length of the epitheca, deflected 20° to the left, pointed at each end, and with the broadly ellipsoidal ventral pore at its anterior end. The hypotheca is narrower and shorter than the epitheca, rotund at the right, and angled ventrally and at the left. Its dorsal

surface is concave and widely overhanging. At each corner is a slender, conical (15°) horn, 0.4 transdiameter long and tapering evenly to the end in a very slender, aciculate tip.

The horns are wide-set and divergent to the right, the right horn 25°, and the left 20°. The postmargin between them is concave but very shallow, and the serrated fin is provided with long teeth. The length of the postmargin is 0.40 and the distance between the tips of the antapicals, 0.66 transdiameter.

The girdle is submedian, tilted ventrally 10°, and displaced distally 0.5 its width. The precingular rim is very prominent, almost horizontal, slightly arched below, and has a narrow, hyaline, ribbed list. The posteingular rim is scarcely developed and quite wanting in the distal quarter. The furrow is a shallow asymmetrical trough, scarcely indented.

The sulcus is reduced to a small narrow slit, deflected distally to the left 20°, with the flagellar pore at its anterior end about the middle of the girdle, with very little enlargement. Its total length is only 0.16 transdiameter. The postsulcal excavation is very wide, 2–3 girdle widths across.

The plates are not sharply outlined by differential ridges except on the dorsal side of the hypotheca. The anterior intercalary 1^a is nearly triangular and lies midway between the girdle and apex, mainly on the dorsal side. Posteingular $7''\,'$ is subtriangular and lies in the side of the ventral depression.

The entire theca, including the girdle, is covered by subregular porulate reticulations, wide-meshed in the midbody, and becoming finer towards the apices. There are 23 polygons across the dorsal side at the precingular rim. Secondary reticulations appear only in one dorsal suture line. The postmargin has a narrow, serrated, ribbed list.

Dimensions: — Length, 85 μ; transdiameter, 60 μ; dorsoventral diameter, 50 μ; antapical horns, 20 μ.

Comparisons: — *Heterodinium spiniferum* has close relations with *H. angulatum* in the expanded girdle and in the deflection of the horns but it is much less globose, its hypotheca being concave dorsally instead of convex as in *H. angulatum*, and it has less angulation in the shoulders. It differs from *H. fenestratum* in the much finer reticulations. The antapicals are more slender than in other species of the genus.

The type locality is Station 4695 in the Easter Island Eddy.

Occurrence: — *Heterodinium spiniferum* was taken (Plate **13**) only once in a haul from 300–0 fathoms on the fifth line at Station 4695 in the Easter Island Eddy where the surface temperature was 74° F. Only one specimen has been seen. It is eupelagic in tropical waters.

Heterodinium fenestratum Kofoid

Plate 7, fig. 1, 4, 5, 6; Plate 15, fig. 14

Heterodinium fenestratum Kofoid, 1907a, p. 179, pl. 8, fig. 47.

Diagnosis: — A medium-sized, symmetrical species; 1.4 transdiameters in length, with a tapering apical horn and equal, sharply pointed antapicals with incurved tips; girdle overhanging; no furrow or postcingular ridge; surface reticulations very coarse, 8 behind the girdle on the dorsal side, each polygon with several pits. Length, 100 (80–120) μ. Rare in the Tropical Pacific in the Peruvian Current, the South Equatorial Drift, and the South Equatorial Current.

Description: — This is a stout, robust species of medium size, and generalized form. The body is quite symmetrical, only slightly elongated, its length 1.4 transverse and 1.8 the dorsoventral diameters. The epitheca slightly exceeds the hypotheca. Basally the epitheca is a low cone of 95°, symmetrical except for a slight ventral flattening and a slight concavity on the left shoulder, the right being straight. As a whole its dorsal side is less concave than the ventral. It is produced into a large stout apical horn, tilted 10° to the left, conical (22°) in shape, with slightly oblique apical pore. Its length is nearly 0.5 of the epitheca. The ventral area appears simply as a wide part of the smooth intercalary band between the plates at the level of the apical-precingular suture. The ventral pore is elongate ovoidal with its axis vertical and a reniform depression at the right. It is located 0.27 of the length of the epitheca above the girdle.

The hyptheca is almost as large as the epitheca at the girdle, almost symmetrical, with its right lateral margin somewhat more convex than the left. In its distal third its sides become parallel as they pass into the stout antapicals. Basally it is almost hemispherical, except for the relatively shallow ventral depression about the sulcus.

The antapicals are stout, subconical (25°), equal, tapering horns of the same length, about 0.20–0.25 transdiameter in length, with sharp, incurved tooth-like points. The postmargin between them is recessed 0.28 and the distance between the tips is a little less than 0.5 transdiameter. The postmargin bears a wide ribbed list.

The girdle is almost median, horizontally displaced 3 girdle widths, with an overlap of almost twice its width. The precingular rim is very narrow and is formed largely by a hyaline ribbed list with sloping surface below. The postcingular rim is entirely lacking and the furrow is indicated only by a slight depression.

The sulcus is very oblique (40°) in its anterior 0.66, then turns sharply into a vertical course, and continues to within 0.33 of the distance from the proximal end of the girdle to the postmargin. High hyaline lists with sinuous margins are formed on either side of it and the right one continues beyond its posterior end. There is no clearly defined postsulcal trough but only a general depression without definite margins.

The plates depart from the normal only in the small size of the anterior intercalary which is a small equilateral triangle on the lower half of the left shoulder mainly on the dorsal side. Postcingular 7″ ′ is elongated. The ventral suture of the epitheca is vertical.

The polygons of the reticulation of the theca are exceptionally large and unequal. They are smaller distally on the horns, in the girdle, and at the end of the sulcus. A single row of rectangular areas of smaller size lies in the narrow girdle. Each of the larger polygons is marked by several (3–9) small pores, instead of by a single central one as in almost all other species of the genus. A few spinules project from the angles of the mesh on the dorsal side of the apical horn. The distal ends of the antapical horns bear a resemblance to spines.

The cell contents (Plate 7, fig. 5) were found intact in one specimen. The cytoplasm was coarsely and uniformly vacuolated. Small homogeneous spherules were scattered through the central mass of cytoplasm. A most unusual feature was a large vacuole in the center of the epithecal region which contracted to a conical opening at the apical pore. On its sides were small scattered rodlets. Another small narrow canal goes from the ventral pore up the ventral side of the vacuole. A small spherical nucleus and a spherical chromosphere lie near the center of the body adjacent to the flagellar pore.

Dimensions: — Length, 102 (80–120) μ; transdiameter, 93 (85–100) μ; horns, 18 μ.

Variation: — The specimens examined were remarkably uniform in form of body and pattern of reticulations. The antapicals were more flaring and less incurved in two individuals and the ventral depression more pronounced in one. There is a little variation in the length of the apical and antapical horns which is reflected in the range in length of the body (80–120 μ).

Comparisons: — Like *H. expansum* and *H. spiniferum*, *Heterodinium fenestratum* has affinities with the subgenus Sphaerodinium in its rather stout build, somewhat globose body, and even more in the spine-like ends of the antapical horns. *H. fenestratum* is, however, placed in the subgenus Heterodinium because of the development of the apical and antapical horns. The incurvature of the

antapicals is like that in *H. fenestratum*. The peculiar type of surface markings with large polygons with several pores distinguishes it at once from any other species in the genus.

The type locality is Station 4730 in the South Equatorial Drift.

Occurrence: — *Heterodinium fenestratum* is recorded (Plate **13**) at fifteen of the 127 stations. There are 0, 4, 3, 3, 3, and 2 on the six lines of the Expedition respectively. Of these fifteen stations, five (4650, 4659, 4669, 4670, 4676) are in the Peruvian Current, nine (4679, 4681, 4705, 4709, 4711, 4721, 4722, 4730, 4740) are in the South Equatorial Drift, and one (4742) is in the South Equatorial Current. At one station only (4669) this species was taken in a surface haul and at one station (4670) in a haul from 800–0 fathoms only. All other records are from hauls from 300–0 fathoms.

The temperature range at these fifteen stations was 66°–81° and the average was 72.3°. This is lower than the average for any other species of the genus. There are but three records above 75°, and six are below 70°.

The frequency at all the record stations was less than 1%.

The distribution of the record stations and temperature records is suggestive that *H. fenestratum* is not prevalent in the warmest parts of the tropical Pacific, but has a preference for the cooler Peruvian Current, and is carried far to the west in the South Equatorial Drift. It is absent from the Easter Island Eddy, where the genus is best represented, and from the warm Mexican Current. All record stations lie between the equator and 20° S.

It is eupelagic, stenothermal in the cooler tropical currents in the deeper levels.

Heterodinium praetextum Kofoid

Plate **7**, fig. 2, 3; Plate **15**, fig. 15

Heterodinium praetextum Kofoid, 1907a, p. 184, pl. 7, fig. 41.

Diagnosis: — A very large species of irregular elongated form; length, 1.3 transdiameters, with long slender apical horn; flaring at the narrow girdle, with impressed furrow; antapical horns stout, subequal, incurved; surface finely reticulated, 43 polygons on the ventral face at the girdle. Length, 240 μ. Rare in the South Equatorial Drift of the Eastern Tropical Pacific.

Description: — This is the largest species known in Heterodinium. Its very asymmetrical body is elongated and much compressed, its length being 1.3 transverse and 1.7 dorsoventral diameters. The girdle is postmedian, located at 0.6 total length from the apex. The epitheca is much larger than the hypotheca.

The epitheca is large and irregularly shaped, with a total altitude of 0.7 transdiameter. It is subconical (60° flaring basally to 90°), convex in the middle of each shoulder, but concave on the dorsal and ventral faces and rather deeply excavated midventrally. The right side protrudes more than the left. It is drawn out into a long, slender, conical (20°) apical horn, inclined 10° to the right, with a squarely truncate apex.

The ventral suture is deflected to the left and is almost right angled at the ventral area. This area is an oblique (20°) subrectangular region, 0.2 of the height of the epitheca above the girdle. The ventral pore is cordate with the indentation directed anterosinistrally and is located at the left end of the area.

The hypotheca is smaller than the epitheca, is subconical (55°), has less flare at the girdle, is concave on the right and convex on the left, is dorsally very abruptly and deeply recessed, and is widely and deeply excavated ventrally.

The antapex is prolonged in two short, stout, conical (50°–60°) horns of less than 0.2 transdiameter in length. Their tips are blunt, their ventral faces angular, and their inner faces quite concave, especially that of the left horn. The left horn is curved ventrally. The postmargin between them is asymmetrically concave, deepest at the right, with a reticulate hyaline fin. The depth is 0.14 and width between tips 0.23 transdiameter, respectively.

The girdle is very narrow, 0.4–0.5 transdiameter wide, and runs almost horizontally round the body in a sinuous course. It is displaced distally its own width. Both precingular and postcingular rims are well developed in the proximal part, but the posterior fades away distally. The precingular is a thin horizontal shelf but the postcingular a much thicker projection. The furrow is deeply and symmetrically impressed, its depth at the left margin being half of its width. The trough fades out dorsally.

The sulcus is a sinuous, or slightly sigmoid, narrow, deep groove, extending 0.8 of the distance from the girdle to the postmargin. It expands anteriorly about the flagellar pore which is large, elliptical, and lies across the proximal end of the girdle. There are no sulcal lists. The posterior end of the sulcus invades the postsulcal area which is deeply concave and 0.28 transdiameter across at its middle and widest part. It merges anteriorly in the general ventral excavation of the hypotheca and is bounded laterally by the angled ventral edges of the antapical horns.

The thecal plates are normal and clearly bordered by wide intercalary bands except in the girdle. The anterior intercalary 1^a is a small triangular plate on the dorsal face only a short distance above the girdle. Postcingular $7''$ ′ is an asym-

metrical, triangular, mainly smooth plate. The thecal wall is covered with fine-meshed, somewhat irregular reticulations, each marked by a central pore. They are somewhat smaller distally on the horns and at the edge of the girdle. Between the plates along one side of the intercalary band, or completely filling it, is a narrow row of minute, often rectangular, secondary polygons. There are 43 polygons along the precingular edge of the girdle. Only four polygons occur on plate 7″ ′.

The cell contents were made out in the one specimen seen which was stained in haematoxylin. The nucleus was remarkably small for so large a cell body. It was ellipsoidal, 0.08 transdiameter in longest diameter with the long axis subvertical, centrally located, and had a faint network of chromatin threads. A large faintly staining mass with coarser granules about 0.5 transdiameter across, lay adjacent to the nucleus, possibly a modified chromoplast. There were two deeply staining, rather small chromoplasts, a small vacuole filled with rodlets, and deeply staining rounded structures adjacent to the flagellar pore (blepharoplasts?) and below the ventral pore. The two were connected by a deeply stained fiber. Coarse granules in the otherwise finely granular cytoplasm were clustered near the apical pore and along the right side. They did not blacken in osmic acid.

Dimensions: — Length, 240 μ; transdiameter, 175 μ; dorsoventral diameter, 130 μ; antapical horns, 20 μ.

Comparisons: — *Heterodinium practextum* is by far the largest member of the genus and has the best developed apical horn. In the inclination of the apical, incurvature of the antapicals, outline of sulcus, and general form it resembles *H. blackmani*, but differs from it in its narrower apical horn, stouter antapicals, wider postmargin, and surface markings. In general shape it is more like other members of the *expansum* group, especially *H. fenestratum*.

The type locality is Station 4740 in the South Equatorial Drift.

Occurrence: — The only record (Plate **13**) of *H. practextum* was in a haul from 300–0 fathoms at Station 4740 in the South Equatorial Drift on the sixth line of the Expedition. The surface temperature there was 81° F.

It is a eupelagic tropical species.

The *dispar* group

Plate **5**, fig. 2, 3; Plates **8**, **9**, **13**; Plate **15**, fig. 20–25

No apical horn (in ventral view); epitheca tapering uniformly; length, 0.8 transdiameter or more; antapicals generally long and spreading.

This group contains six species including *H. dispar* sp. nov., *H. elongatum* Kofoid and Michener, *H. leiorhynchum* (Murray and Whitting), *H. hindmarchii* (Murray and Whitting), *H. curvatum* Kofoid, and *H. blackmani* (Murray and Whitting) all of which occur in the collections of the Expedition.

Heterodinium dispar sp. nov.

Plate **5**, fig. 2, 3; Plate **15**, fig. 20

Diagnosis: — A small stout species, with globose midbody; length, 1.5 transdiameters; epitheca 0.82 transdiameter high; midventral suture very angled, ventral pore large; antapicals very unequal, right sometimes hardly developed; postmargin obliquely asymmetrical; surface sparsely porulate, sutures faint, with a loose reticulation only on the left ventral face of the epitheca. Length, 72 (70–73) μ. Rare in Eastern Tropical Pacific in the Galapagos and Easter Island Eddies and the South Equatorial Drift.

Description: — The midbody is globose, with only slight dorsoventral compression, and divided equally by the horizontal girdle into epitheca and hypotheca. The epitheca is somewhat dorsoventrally compressed and slightly flattened on its ventral face. The apex does not form a horn, and, seen in ventral view, is slightly deflected to the right with a truncate apical pore. It is subconical (70–75°) in ventral view with uniformly slightly concave sides, rarely with a slight bulge at the middle.

The hypotheca is similar in form to the epitheca, but narrower (60°), with slightly concave lateral contour, or even slightly convex below the girdle.

The antapex is very asymmetrical, with the antapical horns very unequal, the left about 0.25 transdiameter long, stout, conical (20° basally contracting to 20° distally), and sometimes with a minute terminal spinule. The right horn is very variable, sometimes scarcely developed, appearing as a blunt angle (90°), or as a short stout cone (60°), less than a girdle width in length, or as a sharper (20°–30°) acute cone. It is deflected to the right from 20° to 45°. The postmargin is obliquely arched, scarcely indented, and measures about 0.5 transdiameter between antapical tips.

The girdle is median on the midbody, horizontal, displaced distally its width, with an overlap of less than 0.5 girdle width. The precingular rim forms a horizontal shelf below, with an overhang of 0.5 girdle width. The postcingular rim

is marked by a low bulge in the wall. The furrow is slightly (0.2 girdle width) impressed and widens out distally to 1.5 its proximal width.

The sulcus is 0.4 transdiameter in length, almost straight, with a single tooth in the right margin. The postsulcal region is a broad shallow depression with no sharp boundaries.

The greater part of the theca is marked only by a few circular pits or pores and by the fine suture lines developed as ridges only at the postcingular rim. It is peculiar in having reticulations developed only on part of the theca, in the few known cases only on the left ventral face of the epitheca on plate 1″, on the proximal end of the girdle, and sometimes on the antapicals and rear of the postmargin. The plates are very faintly marked. The anterior intercalary is an asymmetrical quadrangular plate showing on both dorsal and ventral faces, located in the second quarter of the left shoulder. Postcingular 7‴ is nearly equal to 1‴ and widens out posteriorly. It is larger than in other species.

Dimensions: — Five specimens measured. Length, 72 (68–75) μ; transdiameter, 51.8 (50–57) μ; length of right antapical, 3.2 (0–5) μ; of left antapical, 13.8 (12–17) μ.

Variation: — The size of the right antapical horn varies from about 0.2 transdiameter to a mere angled projection, in shape from a stout to a slender cone, and in deflection from 20° to 90°. The peculiarly incomplete reticulation varies in weight and location. Generally it is present only on the first postcingular and in the proximal end of the girdle. One specimen only had a few polygons on the dorsal side of the postmargin on the side of the left antapical. All specimens seen had this restricted reticulation, so that it seems improbable that this species is only a form of some other one which has recently undergone ecdysis.

Comparisons: — *H. dispar* is included in the subgenus Heterodinium on account of its flattened and excavated epitheca, but it falls between it and Sphaerodinium in many features.. It is near *H. globosum* in disproportion of antapicals and scanty reticulation. It differs from it in absence of apical horn (in ventral view), less globose body, lower and larger ventral pore, deeper furrow of girdle, and less ventral deflection of antapicals. It differs from the next member in the *dispar* group, *H. elongatum*, in its stouter form, relatively shorter epitheca, and asymmetry of its antapicals. It is rather near *H. leiorhynchum* but is less globose, its apex is less curved to the left, its antapicals are much more unequal, and lack the terminal spinules. It also lacks the doubled ribs along the lateral apical sutures.

The type locality is Station 4683 in the South Equatorial Drift.

Occurrence: — *Heterodinium dispar* is recorded (Plate **13**) as fairly widely distributed over the southern part of the track of the Albatross Expedition, being found at thirteen of the 127 stations. There are 0, 0, 5, 5, 3, and 0 stations on the six lines of the Expedition respectively. Of these thirteen stations one (4713) is in the Galapagos Eddy, eight (4679, 4683, 4685, 4701, 4705, 4722, 4724, 4732) are in the South Equatorial Drift, and four (4691, 4692, 4695, 4699) are in the Easter Island Eddy. At Station 4692 it was taken in a surface haul and at the other twelve, in hauls from 300–0 fathoms. The frequency reached the unusual level of 1% at five stations (4683, 4685, 4692, 4695, 4701). The surface temperatures were from 69° to 79° F., averaging 74.2°. There were only two records above 75°.

Heterodinium dispar is one of the more common species of the genus. It is eupelagic and eurythermal, is noticeably rare at the surface, and has a predominance in the center of the South Equatorial Pacific between 5° and 25° S. It is absent from the cold Peruvian Current, from the Panamic Area, and was not found north of the equator.

Heterodinium elongatum Kofoid and Michener

Plate **8**, fig. 1–3; Plate **15**, fig. 21

Heterodinium elongatum Kofoid & Michener, 1911, p. 284.

Diagnosis: — A small species with symmetrical conical epitheca 0.9 transdiameter high; midventral suture slightly arched; apical region not curved; antapicals equal, conical, not curved; sutures lightly ribbed; reticulation complete, 10 polygons from girdle to apex. Length, 62–80 μ. South Equatorial Drift and Equatorial Counter Current of the Eastern Tropical Pacific.

Description: — A small, slender, erect, rather symmetrical species with elongated body whose length is 1.6 transdiameters. The epitheca is about equal to the hypotheca and girdle together. The dorsoventral diameter is almost exactly equal to the transverse at the precingular ridge. The epitheca is 0.9 transdiameter in height, conical (60°) in ventral view, with slightly convex sides. The ventral face is nearly flat, with a median ventral depression, its slope ventrally deflected 28° from the vertical axis, and its dorsal side flaring in the proximal 0.66 in dorsal view, with an almost hemispherical bulge to the precingular rim. This sets off dorsally an apical horn in lateral view only, of conical (35°) outline, dilated dorsally, with an obliquely truncated apical pore sloping down

dextrodorsally. The midventral suture arches to the left. The ventral area is a subtriangular region to the left of the suture midway between girdle and apex. The ventral pore has a broadly reniform outline with the indentation facing the right.

The hypotheca is shorter than the epitheca, 0.66 transdiameter in extreme length, slightly angular at the sutures, but subhemispherical aside from the antapical horns. It is more convex dorsally than ventrally and the horns lie nearer the ventral than the dorsal side. It is rather deeply excavated ventrally with angular borders about the depression.

The antapical horns are equal, though in some specimens the left is a very little smaller than the right. Both are symmetrically conical (25°), spreading 10° from the vertical, pointed, and without spine or fins, though ridges of the surface reticulation run to the tip on some specimens. The indentation of the postmargin between them is symmetrical, its depth is 0.15, and the distance between the tips of the antapicals is 0.40 transdiameter. A hyaline toothed fin borders the central part of the arched postmargin.

The girdle is relatively very wide, 0.17 transdiameter across, nearly the same width throughout, except at the extreme distal end where it flares abruptly and is displaced posteriorly its own width. There is scarcely any overlap. The precingular ridge is somewhat more protuberant than the postcingular. It does not flare, or flares but little, is arched below, and runs a smooth even course. The postcingular ridge is indented posteriorly at the proximal end for a short distance and becomes increasingly deficient in the distal quarter where it curves rapidly posteriorly. It is formed by a blunt angle of the body wall. The furrow is impressed throughout, more deeply in the proximal end, and becoming shallower distally. Its depth is about 0.5 girdle width and the trough is asymmetrically deeper anteriorly.

The sulcus is almost straight and vertical, 0.4 transdiameter in length, narrowly contracted near the middle, and expanded in the furrow into the rectangular flagellar pore. There are no sulcal lists. A deep, trough-like postsulcal area lies behind the sulcus, bordered by angular elevations on the ventral faces of the antapicals.

The thecal wall is reticulate throughout, including the girdle, but, excepting postcingular plate 7″ ′, is entirely smooth. The polygons in the girdle which are reticulate throughout, are arranged in two rows, the lower quadrangular or pentagonal, the upper smaller and somewhat hidden in the arching precingular list. The polygons elsewhere are quite large and subuniform in size, except towards

the apex where they decrease in size. They tend to be rectangular and there are only two or three rows in the plates adjacent to the girdle. Each polygon bears a single central pore. Secondary reticulations were seen only on the dorsal postcingular ridge in the specimen figured (Plate 8, fig. 1–3). On another specimen they were numerous along all the main sutures. There are 19 polygons along the precingular ridge and 8–10 from the girdle to the apex on the dorsal face. The sutures between the plates are clearly marked by ridges heavier than the reticular mesh. The anterior intercalary is an irregular quadrilateral midway on the left shoulder. Postcingular 7″′ is two girdle widths in length, widest (nearly a girdle width) in its posterior third, and devoid of mesh or pores.

The cell contents were observed only in a single specimen. The cytoplasm was rounded up in a spherical mass filling the midbody. Near the center was a spherical nucleus, a girdle width in diameter, adjacent to a spheroidal chromosphere.

Dimensions: — Length, 73.6 (62–80 μ); transdiameter, 48.2 (40–57) μ; dorsoventral diameter, 35.5 μ; right antapical horn, 10.6 (7–12) μ; left antapical horn, 11 (8–13) μ.

Variation: — The epitheca varies in lateral contour from nearly straight to slightly convex with some precingular flare. There is also some variation in the degree of angularity of the hypotheca. The specimen figured (Plate 8, fig. 1–3) is near the extreme in this feature. The apical pore varies from transverse to oblique and the antapicals range from 25° to 40° in their conical contour. They are quite constantly nearly equal in contour, length, and deflection from the vertical, differing in this respect from *H. scrippsi*, in which their inequality in these three features is considerable. There is also some variation in the frequency of the secondary polygons along suture lines correlated with the development of the intercalary zones.

Comparisons: — *Heterodinium clongatum* lies between *H. leiorhynchum* and *H. hindmarchii* in the *dispar* group. It differs from the former in the much greater development of reticulations, the greater equality of the antapicals, lack of curvature in the apical region, and in the absence of terminal spinules on the antapicals. It differs from the latter in the shorter straight antapicals, as compared with the longer arched ones of *H. hindmarchii*. The sulcus in the latter species is short and wide, in the former very narrow. The epitheca is also stouter and the reticulations heavier and more uniform in *H. hindmarchii*. There is considerable resemblance between *H. elongatum* and *H. scrippsi* of the *crassipes* group. *H. scrippsi* has unequal, more divergent antapicals, more expanded and

angled shoulders on the epitheca, and 15 instead of 10 polygons between apex and girdle on the dorsal side; in other words, the polygons are relatively more numerous. *H. scrippsi* is also larger, 140–155 μ (in Expedition collections 115 μ) as compared with 62–80 μ.

The type locality is Station 4724 in the South Equatorial Drift.

Occurrence: — *Heterodinium elongatum* occurred (Plate **13**) at seven of the 127 record stations. There are 0, 0, 2, 1, 3, and 1 stations respectively on the six lines of the Expedition. Of these seven stations, six (4679, 4681, 4701, 4724, 4732, 4734) are in the South Equatorial Drift, and one (4742) in the Equatorial Counter Current. The species was not taken in any surface haul, six being from 300–0 fathoms and one (4681) from 800–0 fathoms.

The temperature range at the seven stations at the surface was 68°–81° and the average 75°.

The frequency at all stations was less than 1%.

This species is eupelagic, and tends to be stenothermal at the higher temperatures of the tropical Pacific. The records are confined to well-established tropical conditions and there is an avoidance of the surface levels. It is absent from the Peruvian Current and the Panamic Region.

Heterodinium leiorhynchum (Murray and Whitting)

Plate **15**, fig. 22

Peridinium leiorhynchum Murray & Whitting, 1899, p. 326–327, pl. 29, fig. 2a, b.
Heterodinium leiorhynchum Kofoid, 1906a, p. 358; Entz, Jr., 1909, p. 246.

Diagnosis: — A medium-sized species with very globose midbody; epitheca 0.75 transdiameter high; midventral suture slightly angled, ventral pore small; apex curved to right, lateral apical sutures with double ribs; antapicals slightly unequal, the right 0.50–0.66 length of the left; sutures ribbed; reticulations sparse, restricted to left ventral face of the epitheca and proximal girdle. Length, 95 μ. Eastern Tropical Pacific, Atlantic Ocean, and Mediterranean Sea.

Description: — This is a medium-sized, stout, rotund species, with a total length of 1.55 transdiameters. The epitheca and hypotheca are subequal, and the apical and antapical horns are vertical in lateral view. The epitheca in ventral view is almost an equilateral triangle, subconical (55°–60°), flaring a bit at the girdle, with the left margin concave, and the right slightly convex in the middle. In lateral view the epitheca shows a sharp distinction between the globose midbody and a distinct apical horn which is entirely obscured in the ven-

tral view. The epitheca is somewhat flattened dorsoventrally, its diameter in that axis at the girdle being 0.82 transdiameter. The midbody in this view is subconical (90°) with slight dorsal tilt and forms 0.5 the total altitude of the epitheca. The apical horn is conical (20°), 0.5 the total epitheca in height, and with a truncate apex, lipped where the lateral ridges end. In ventral view it is noticeably curved to the right. The midventral suture is only slightly deflected. The ventral pore is 0.33 of the length of the epitheca above the girdle. It is small and circular in outline.

The hypotheca is basally hemispherical, excavated midventrally, and terminates in two prominent antapical horns. They are unequal, the left being 1.5 the length of the right. Both are conical, the right 25°, the left 30°, and each bears an acute terminal spinule about 0.25 its length in length. They diverge unequally, the right about 10° and the left about 20° from the vertical. The postmargin between them is deeply and asymmetrically arched, being deeper at the right. Its depth is 0.33, and the distance between the tips is 0.56 transdiameter.

The girdle is median in location, tilted a trifle ventrally, displaced posteriorly at its distal end one girdle width, and without overlap. The girdle is unusual in this species in that it grows narrower instead of wider distally, being about half as wide in the distal quarter as in the adjacent proximal quarter. The precingular and posticingular rims are subequal, the latter being deficient dorsally. Both are very low ridges. The furrow between them is flat.

The sulcus is short, barely two girdle widths in length, rather sharply angled, with spinous fin on the right margin. The postsulcal area is not sharply limited and is very short, scarcely a girdle width in length.

The thecal wall is sparsely porulate and is reticulated only on the ventral face over precingular plate 1″ and in the proximal quarter of the girdle. Small secondary polygons follow the suture between precingulars 5″ and 6″ and in the postcingular rim. There are only six polygons at the precingular rim. The polygons in the girdle consist of a single large posterior row and above them a row of more numerous smaller ones. The suture lines are generally heavily ribbed, the lateral apicals bearing parallel double ribs. The plates are clearly outlined, except in the girdle. The anterior intercalary, 1ª, lies on the dorsal side midway between the girdle and apex. Postcingular 7″ ′ is very wide and short.

Nothing is known of the cell contents.

Dimensions: — Length, 95 μ; transdiameter, 62 μ; dorsoventral diameter, 50 μ; length of right antapical, 16 μ, of the left, 25 μ. Five specimens were measured.

Variation: — Our single specimen has a somewhat more tapering (45°) epitheca than in Murray and Whitting's figure (their pl. 29, fig. 2a), has a shorter right antapical (0.5 the length of the left), and has reticulations on the tip of the left antapical.

Comparisons: — *Heterodinium leiorhynchum* differs from all other members of the *dispar* group in having well differentiated spinules on the tips of the antapicals. Its apical horn, in lateral view, is similar to that of *H. blackmani*, but shorter. Its antapical horns are more unequal than in any other species of the group except *H. dispar* and are more divergent than in *H. elongatum*. Its reticulations are restricted in the same general manner as in *H. dispar* and are much coarser than in *H. blackmani*, *H. curvatum*, *H. elongatum*, and *H. hindmarchii*.

Synonymy: — This species was described by Murray and Whitting (1899) as *Peridinium leiorhynchum* and transferred to Heterodinium by Kofoid (1906a).

The type locality is 20°–40° N., 30°–50° W. in the warm temperate Atlantic (Murray and Whitting, 1899).

Occurrence: — *Heterodinium leiorhynchum* occurred (Plate **13**) at only a single station (4697) on the fourth line of the Expedition in the Easter Island Eddy in a haul from 300–0 fathoms at a surface temperature of 75°.

This species was first reported at two stations by Murray and Whitting (1899) from the warmer temperate and tropical Atlantic from 20° to 40° N. and 30° to 50° W. in March–April at surface temperatures of 60°–76°. Entz, Jr. (1907, 1909) recorded it at Naples in November.

Heterodinium hindmarchii (Murray and Whitting)

Plate **8**, figs. 5, 7; Plate **15**, fig. 23

Peridinium Hindmarchii Murray & Whitting, 1899, p. 326, pl. 29, fig. 1a, b.
Heterodinium hindmarchi Kofoid, 1906, p. 359.

Diagnosis: — A medium-sized, rather elongated species, with tapering, slightly inclined epitheca; total length, 2.0 transdiameters; antapicals 0.6 transdiameter long, widely separated, asymmetrically divergent and incurved; surface completely reticulated with uniform or unlike polygons. Length, 124.2 (118.0–128.0) μ. Rare in the tropical Atlantic and also in the Pacific in the Mexican Current, South Equatorial Drift, and Easter Island Eddy.

Description: — This is a medium-sized species of robust habit. The body is elongated to a total length of 2.0 transdiameters, chiefly because of the extension of the epitheca which is evenly drawn out towards the squarely truncated

apex. The epitheca equals the hypotheca and the girdle. Its extreme ventral altitude is 1.07 transdiameters. It is conical (45°) with almost symmetrically concave sides, flaring only a little towards the girdle, the left a little more concave than the right, and is flattened on the ventral face. The ventral area is broadly subtriangular, with a centrally located, subcircular ventral pore with a reniform indentation facing horizontally to the right.

The hypotheca is subhemispherical measured from the postcingular level and excluding the antapicals. It is, relatively to the hypotheca, short and broad, with a short concave right and a longer convex left lateral margin and a shallow ventral depression.

The antapical horns are subconical (right 12°, left 20°), long and slender, usually bluntly pointed, but in some individuals with an abrupt acute tip. They are usually incurved, the shorter right horn more than the longer left. The right is about 0.4, the left 0.4 transdiameter long. The postmargin is deeply arched and the indentation asymmetrically inclined to the right. The horns diverge unequally, the right 15°, the left 27° from the vertical. The depth of the excavation is 0.37 and the distance between the tips of the antapicals 0.86 transdiameter.

The girdle is almost median in the midbody, but one girdle width postmedian in the body as a whole. It is subhorizontal, tilted a bit dextroventrally and displaced distally its width, and is without overlap. The precingular margin steeply overhangs, is arched below, and forms a smooth regular curve. The postcingular rim is wanting or, at the most, is represented by a trace of a local bulge in the proximal part only. The furrow is not impressed.

The sulcus is short, 0.24 transdiameter in length, very narrow, almost straight, and without lists. The postsulcal area is set off by a low elevation on either side. Its width is twice its height and no list was seen on the postmargin.

The thecal wall including the girdle, but excluding postcingular plate 7″ ′, is entirely and rather uniformly reticulated, with subregular porulate polygons. There are 12 polygons between the apex and the girdle and 13–15 at the precingular rim on the dorsal face. The sutures between the plates are obscured by the mesh. The anterior intercalary plate 1ᵃ is asymmetrically quadrangular, almost triangular, and lies below the middle of the left shoulder on the dorsal side. Postcingular 7″ ′ is nearly equal to 1″ ′, is broader than usual, and is not always reticulated.

The cell contents were found intact in one individual of forma *maculata*. The finely granular plasma filled the theca. The small, ellipsoidal nucleus is

centrally located just below the girdle and is a girdle width in long diameter. Adjacent to it is a slightly larger, spherical, greenish yellow chromosphere, almost surrounded by a vacuole and two girdle widths in diameter. Several small, spherical, dark greenish chromoplasts lie along the periphery at the girdle level.

Dimensions: — Length, 124.2 (118–128) μ; transdiameter, 61.8 (62–65) μ; right antapical, 30 (25–33) μ; left antapical horn, 33.8 (32–39) μ. Murray and Whitting's specimen is larger and measures: length, 137 μ; transdiameter, 67 μ; antapical horns, 35 and 40 μ, respectively.

Variation: — This is most obvious in the degree of elongation of the body, the specimen figured by Murray and Whitting (1899) being longer than those from the Pacific. There is a fair range of variation in the length, curvature, and deflection of the antapical horns.

Status of Heterodinium hindmarchii forma *maculatum* Kofoid: — In the first preliminary account of the dinoflagellates of the Expedition, Kofoid (1907a) described as forma *maculata* the specimen here figured (Plate 8, fig. 5, 7). It was distinguished by reason of the very characteristic surface reticulations. These differ notably from those on Murray and Whitting's (1899, pl. 29, fig. 1a, 1b) specimen in number, pattern, and especially in uniformity. The eight other specimens in the collections of the Expedition all conform in these characters to the type as figured by Murray and Whitting.

The evidence in the genus as a whole leads us to regard secondary reticulations which appear along the intercalary zones on the edges of the primary reticulations as phenomena related to the increase in size prior to ecdysis. The widening of the intercalary zones between the plates is followed or accompanied by the spread of smaller, non-porulate, often rectangular reticulations along the sides, or even completely filling these zones.

The specimen designated as forma *maculata* conforms to these specifications in that it has intercalary zones, and small rectangular polygons bordering these zones, in the usual fashion. It has, however, one additional feature which in our present knowledge of the process of growth preceding ecdysis and division, is difficult to explain as a part of that process and is also without parallel elsewhere in the data from this genus.

This disturbing feature is the presence in forma *maculatum* of small non-porulate polygons not only along the suture lines but also in a somewhat regulated manner between polygons *within* the plates, as for example in the dorsal pre- and posteingular plates (Plate 8, fig. 5, 7) in the three apicals, in the upper part of the girdle, and seemingly over the entire surface of the antapical horns.

The plates of the theca of Heterodinium are separable structural units, parted by sutures. The intercalary zone seems to be formed by expansions of these units by the addition of growth-regulated zones on their periphery. On this basis the appearance of secondary polygons on these expanding zones as they emerge is understandable, but their emergence as the result of growth *between the old polygons* is difficult to postulate, especially as there is no evidence elsewhere within the Dinoflagellata of such a degree of separability or unitary regulation of polygons as this hypothesis demands.

Comparisons: — *Heterodinium hindmarchii* is the smallest of the four large species which terminate the *H. dispar* group, the other three being, *H. trirostre*, *H. curvatum*, and *H. blackmani*. It lacks the ventral subsidiary, left antapical of *H. trirostre*, has relatively stouter antapicals than any of them, less development, less curvature of the apical than either *H. curvatum* or *H. blackmani*, and has much more developed, more divergent antapicals than *H. dispar*, *H. leiorhynchum*, or *H. elongatum*.

The excessive rotundity of this specimen, the wide intercalary zones, and the marginal secondary polygons along sutures, all support indubitably the conclusion that this specimen is approaching ecdysis. That the large number of small secondary polygons distributed within the various plates which, in part, give the thecal wall of this specimen its unusual appearance, is also merely a part of the preparatory process and not a genetically differentiating structure, is at least questionable, and certainly puzzling. We therefore retain the designation *forma maculatum* to draw attention to the need of more evidence on the process of ecdysis and especially on the extent of the regulative changes which attend this and other modifications of the dinoflagellate thecal wall.

Heterodinium hindmarchii forma *maculatum* is represented in the collections of the Expedition by two specimens, taken with the typical form of the species, at Stations 4691 and 4699 on the third and fourth lines of the Expedition in the Easter Island Eddy in hauls from 300–0 fathoms where the temperatures at the surface were 73° and 75° respectively.

Synonymy: — Originally described as *Peridinium Hindmarchii* by Murray and Whitting (1899), this species was transferred to Heterodinium by Kofoid (1906a). The forma *maculatum* described by Kofoid (1907a) may be an old individual in which intercalary growth is taking place along with secondary reticulation of the theca, especially in the intercalary zones.

The type locality is 34° N., 39° W. southwest of the Azores in the Atlantic.

Occurrence: — *Heterodinium hindmarchii* is one of the more common species of the genus. It is recorded (Plate 13) at ten of the 127 record stations. There are 2, 0, 1, 4, 3, and 0 respectively on the six lines of the Expedition. Of these ten stations, two (4605, 4609) are in the Mexican Current, four (4701, 4719, 4724, 4737) in the South Equatorial Drift, and four (4691, 4695, 4697, 4699) in the Easter Island Eddy. There is a center of occurrences (5 stations) to the north of Easter Island but the remaining records are widely separated. All are from hauls from 300–0 fathoms, except one (4737) from a vertical haul from 100–0 fathoms. The temperature range at these ten stations was 72°–85° and the average was the rather high figure of 77.1° F.

The frequency was always less than 1%.

It also occurs in the tropical Atlantic. Murray and Whitting (1899) report it from eleven stations from about 34° N, 39° W, to Panama from July to December at surface temperatures of 60°–81°, but never in abundance.

This species is very evidently both eupelagic and eurythermal, but is confined to lower levels in the collections of the Expedition, at least. It has a wide distribution but is infrequent. Its centers of occurrence are clearly in the warmest parts of the tropical seas.

Heterodinium curvatum Kofoid

Plate 8, fig. 4, 6; Plate 9, fig. 5, 6, 8; Plate 15, fig. 24; Plate 17, fig. 41

Heterodinium curvatum Kofoid, 1907a, pp. 164, 179, pl. 8, fig. 48.
Peridinium pulchrum Hensen, 1911, p. 174, fig. C 8, Tab. XVI, non Tab. XVII (= *Peridinium "porosum"*).

Diagnosis: — A large, elongated, slender species; total length, 1.8 transdiameters; epitheca very slender distally, apex much curved to the right and dorsally; postcingular ridge developed throughout; sulcus stops 0.66 of the distance from girdle to postmargin; antapicals stout, both incurved distally, tips bluntish; surface reticulated throughout with small subuniform polygons which along the apical sutures are rectangular, not horizontally elongated. Length, 218 (200–235) μ. Eastern Tropical Pacific in the Mexican Current, Easter Island Eddy, and the Equatorial Drift and Atlantic.

Description: — This is a large, much elongated, asymmetrical species of slender habit, its length 1.67–1.75 transdiameters, and its dorsoventral diameter 0.78 the transdiameter. The epitheca and hypotheca are equal in length in the

middorsal region but in ventral view the hypotheca is 0.8 the length of the epitheca. The epitheca in ventral view is subconical (45° basally, decreasing to 30° distally), with a straight left margin and concave right, especially towards the apex, due to the dextral curvature (20°) of the apical horn. In ventral view this horn is not differentiated by constriction as it is in the lateral views. There is some flare at the girdle, convex at the right, concave at the left. In lateral view the apical horn is set off by an abrupt change in flare at about 0.33 of the distance from girdle to apex, below which the epitheca is a cone of 90°, and above of 20°, but with marked dorsal curvature and an obliquely truncate apex sloping dextrodorsally. The dorsal side is a symmetrical concave curve, the ventral convex in the upper 0.66, straight in the lower 0.33, and depressed in the midventral region.

The hypotheca basally is asymmetrically subconical, 55° in ventral view, and 70° in lateral, somewhat angular on the dorsal face and concave with deep, ventral sulcal excavation.

The antapical horns are subequal, the right a bit longer than the left, and approximately 0.5 transdiameter in length. They are subconical, distally about 20° but increasing basally, the right to 30°, the left to 45°. Each has a prominent midventral ridge. They are incurved in their distal 0.33, the left more than the right, with bluntish tips, the left sharper than the right. In lateral view the median ridge on the ventral surface gives the appearance of a secondary point near the tip. The postmargin is arched, asymmetrically concave, and deepest at the right. The distance between the tips is 0.62 and the depth of the excavation 0.43 transdiameter. The postmargin bears a low, dentate, hyaline list over most of its edge.

The girdle is postmedian, tilted 20° ventrally from the horizontal, displaced distally scarcely its own width, with no overlap, and a slightly sinuous course on the dorsal face. It is of uniform width throughout and its postcingular ridge is almost as well developed as its precingular one. The girdle is nearly uniform in width throughout. Its two ridges are heavy triangular projections and the furrow between them is almost symmetrically impressed, being only a trifle deeper posteriorly. There is scarcely any fading out of the postcingular rim in this species, a feature so widely prevalent in most other species of the genus. The girdle is also rather narrow, being only 0.07 transdiameter across.

The sulcus is 0.33 transdiameter in length, very narrow, except where it expands anteriorly into the flagellar pore at the proximal end of the girdle. It is deflected to the left and is slightly sinuous. There are no lists. There is a very

wide and short (1.3 girdle widths) postsulcal trough between the ventral ridges on the antapicals.

The plates are clearly defined by either ridges or narrow intercalary zones. Each lateral apical suture bears a low hyaline fin. The midventral suture is gently curved, concave to the right, and the ventral area not clearly defined at its junction with the apical-precingular horizontal suture. The ventral pore is elongated reniform with the concavity obliquely facing the right. The anterior intercalary is an asymmetrical quadrilateral plate with sinistrodorsal exposure just below the middle of the left margin forming the second quarter of the length of that margin. Postcingular 7″ ′ is of a peculiar shape, somewhat like a broad paddle with the narrow handle in the distal end of the girdle. It is unusually wide (2 girdle widths) and squarish posteriorly. It is the only plate, outside of the girdle, which is not reticulated.

The surface of this species is heavily reticulated with subuniform, rather small, porulate polygons. They are often rectangular along suture lines but are not elongated as in *H. blackmani*. They fade out at the apex and tips of the antapicals, are wholly lacking on postcingular 7″ ′, on the left ventral face below postcingular plate 1″ ′, and in the posterior half only of the furrow. Two rows of small polygons lie in the upper half of the furrow. Very minute, secondary, non-porulate reticulations were seen along the sutures in one specimen in this species, probably approaching ecdysis, as its intercalary bands were well developed. There are about thirty-five polygons at the girdle along the precingular ridge and twenty-four from girdle to apex along the midventral suture.

The cell contents are unknown beyond the observation of a yellowish brown chromosphere in one individual.

Dimensions: — Length, 218 (200–235) μ; transdiameter, 130 μ; dorsoventral diameter, 110 μ; right antapical, 58 μ; left antapical, 54 μ.

Variation: — Our material was quite uniform, with reticulate surface, and marked curvature of the horns. One specimen from Station 4587 had wide intercalary zones, maximum size (235 μ), secondary polygons along sutures, and a stouter but more curved apical horn. It was probably approaching ecdysis.

Comparisons: — *Heterodinium curvatum* is very close to *H. blackmani* in size, general shape, pattern of antapicals, and curvature of the apical. *H. curvatum* has a more slender apical region, stouter and blunter antapicals, and its sulcus runs only 0.66 posteriorly from the girdle towards the postmargin, while in *H. blackmani* it runs all the way. The most striking difference is in the extent and

pattern of the reticulations. The reticulations cover the entire surface, with the very small exceptions noted above, in *H. curvatum*, but tend to be either wholly lacking, or feebly developed, in the pre- and postcingular plates, except 1″, in *H. blackmani*. Postcingular plate 7″ ′ in *H. curvatum* is very broad and paddle-shaped, while in *H. blackmani* it does not narrow into the handle-shaped projection in the girdle region and is not so broad posteriorly. For these several reasons we do not regard *H. curvatum* as an *H. blackmani* with more completely developed surface reticulations. Such development could scarcely bring about such considerable changes in the pattern of the polygons, the shape of postcingular 7″ ′, and the sulcus. Murray and Whitting's (1899, pl. 29, fig. 2a, 2b) figures of this species present certain anomalies in structure which our figure (Plate 9, fig. 4) clarifies. They have drawn the ventral face of the epitheca without any ventral suture, ventral area, or ventral pore. The pattern of reticulation, both as to number and shape of the polygons, is suspiciously similar to that which they figure for the *dorsal* surface. We conclude that they focused on the dorsal surface and drew it in their figure as though it were the ventral. In any event their figure is anomalous and incorrect in the matter of reticulations on the ventral face of the epitheca.

Synonymy: — Hensen (1911, p. 174, fig. C 8) published as *Peridinium pulchrum* an inverted and very imperfect figure of Heterodinium which is probably this species, though he figures no sulcus and the reticulations are diagrammatically drawn with certain regions blank. The reticulations are so placed in his sketch that one is led to infer that the blank areas were also reticulated, at least they do not correspond in location to the usual blank. Because of the small size of the polygons, complete reticulation, and the very tapering epitheca, we tentatively place this form of Hensen's in *H. curvatum*. Its extensive distribution in the Atlantic is comparable with that found in the collections of the Expedition from the Pacific.

The type locality is Station 4699 in the Easter Island Eddy.

Occurrence: — *Heterodinium curvatum* is recorded (Plate 13 and Plate 17, fig. 41) at seventeen of the 127 stations. There are 4, 0, 6, 6, 1, and 0 stations respectively on the six lines of the Expedition. Of these seventeen stations, four (4583, 4587, 4590, 4594) are in the Mexican Current, seven (4679, 4680, 4687, 4688, 4701, 4705, 4739) are in the South Equatorial Drift, and six (4691, 4692, 4697, 4698, 4699, 4700) are in the Easter Island Eddy. At six stations (4590, 4680, 4688, 4692, 4698, 4700) the species was taken in surface hauls. The other eleven records are from 300–0 fathoms. The temperature range at the seventeen

stations at the surface was 68°–84° and the average was 75.4°. Ten of the seventeen records are at temperatures of 72°–75°.

The frequency was 3% at Station 4692 and 2% at 4698, both surface hauls, and 1% at 4700. The frequency at the other fourteen stations is less than 1%.

Hensen (1911) reports this species as *Peridinium pulchrum* at twenty stations in the tropical Atlantic distributed as follows: five in the Eastern and four in the Western South Equatorial Current, two off the coast of Brazil, four in the Guinea Current, one in the South Equatorial Current, one in the Sargasso Sea (1 specimen), three in the Gulf Stream, and one in the North Sea. The computed number taken was 317 and the greatest abundance was recorded in the Western South Equatorial and Guinea Currents. It is quite probable that records for *H. blackmani* are included with his for this species.

This species is eupelagic, eurythermal, and has a wide distribution. It has a marked center both of occurrences and frequency in and near the Easter Island Eddy and another small group in the warm Mexican Current. The scattered records in the South Equatorial Drift are in waters to which the Easter Island Eddy is to some extent tributary. The most striking feature of the occurrence of this species is its relative frequency in surface collections. The records of 3% at Station 4692 and 2% at 4698 are not equalled by any other species in the genus Heterodinium. There are in all six records in the total of seventeen, from surface hauls. There are, however, only seventeen records in all from surface hauls for all species of the genus. Therefore this species, more than any other in the genus, shows an ability to thrive in surface waters. There are only two species in the genus which exceed it in number of occurrences, namely *H. rigdenae* with twenty-three and *H. milneri* with nineteen. It is one of the dominant species of the genus.

Heterodinium blackmani (Murray and Whitting)

Plate 9, fig. 1–4, 7; Plate 15, fig. 25

Peridinium Blackmani Murray & Whitting, 1899, p. 327–328, pl. 29, fig. 6a, b, c.
Heterodinium blackmani Kofoid, 1906a, p. 358; Karsten, 1907, p. 238, 243, 244, 274, pl. 47, fig. 6a, b.

Diagnosis: — A very large, stout, handsome species; length, 1.7 transdiameters; epitheca 1.0 transdiameter high, an asymmetrical cone of 50° curved dextrally, flaring at the girdle; postcingular ridge equally developed throughout; sulcus extending to the postmargin; antapical horns slender, subequal, the left incurved; surface coarsely, irregularly, and partially reticulated, polygons along the

sutures between apicals horizontally elongated. Length, 230 (220–270) μ. Rare in tropical seas, Atlantic, Indian, and Eastern Tropical Pacific in the Mexican Current, Easter Island Eddy, and South Equatorial Drift.

Description: — This is next to the largest and one of the most striking members of the genus. The body is much elongated, about 1.7 transdiameters in length, much expanded at the girdle, with a somewhat globose midbody, but flattened dorsoventrally distally. In ventral view it has a stout habit. The length of the epitheca at the midlateral girdle is 1.25 that of the hypotheca. In ventral view, the epitheca is asymmetrically subconical, 65° basally, narrowing to 40° distally. The right side is symmetrically concave, the left nearly straight, except towards the apex which is deflected about 25° dextrally. There is scarcely any increase in flare at the girdle. There is no differentiated apical horn in the ventral view, but in the lateral, the midbody abruptly contracts at the level of the apical-precingular sutures into a slender symmetrical zone (17°), deflected dorsally 7° from the perpendicular to the plane of the girdle. The apex contracts at the oblique apical pore. The ventral suture is straight, angled at the apical-precingular suture. The ventral area is not marked off by any special markings. It lies at the junction of the midventral suture and the apical-precingular one. The ventral pore is small, ellipsoidal, reniform, with an indentation on the right side. In one case it was possible to detach the ventral plate as a distinct platelet of irregular quadrangular shape with the reniform ventral pore in its center (Plate 9, fig. 7). The midbody in lateral view is asymmetrically subglobose, excavated midventrally, with the longer slant on the anterior ventral and posterior dorsal faces.

The hypotheca is about equal to the epitheca on the dorsal face, and is 0.66 its length ventrally. Basally in ventral view it is a cone of about 65° with concave sides spreading distally in the two antapicals. The ventral face is deeply excavated.

The antapical horns are conical, the right 30°, the left 25°, sharp-pointed, the right straight, deflected dextrally 25° from the vertical, the left deflected sinistrally and sharply incurved in its distal third. Both are slightly deflected ventrally and are ribbed down the midventral surface. The postmargin is asymmetrically curved, deflected to the right with more of a tendency towards an angular outline than in related species. The postmargin bears a narrow, hyaline, minutely serrated, sometimes faintly reticulated fin. The distance between tips is 0.61 and the depth of the indentation is 0.40 transdiameter.

The girdle is narrow, 0.045 transdiameter wide, runs a smooth course, is dis-

placed posteriorly its own width at its distal end, and has no overlap. The pre- and postcingular ridges are low and stout, without lists, and the latter is only a trifle less developed than the former, even to its distal end. The furrow is symmetrically impressed into the wall about 0.5 its width. The plane of the girdle is tilted ventroposteriorly not over 15° from the vertical axis.

The sulcus has the unusual form in this species of an asymmetrical channel extending from the large flagellar pore in the proximal end of the girdle, the whole distance to the postmargin. It widens out and bends to the left below the girdle to nearly a girdle width, and, beyond this, is a straight narrow channel in its distal third. A heavy rib borders it on the left anteriorly and a high hyaline list overhangs the right side.

The plates are marked off by very prominent ribs or lists. The latter are doubled between apical plates 1′ and 2′, and 2′ and 3′, along the lateral margins of the apical region, and in some specimens these two lists are continued (Plate 9, fig. 4) part of the way towards the girdle along the sutures between precingulars 1″ and 2″, 4″ and 5″, and 5″ and 6″. Narrow intercalary zones have been seen in some specimens, while in others only narrow ribs occur at the sutures. The anterior intercalary is an irregular quadrilateral in the second quarter of the left shoulder above the girdle on the dorsal side. Postcingular 7‴ is almost quadrangular and is widely expanded in the girdle. Six girdle plates were definitely located in this species.

The surface is only partially reticulated. The parts exempt from this differentiation are the distal members of the precingular row of plates, the postcingulars, and the ventral antapicals in part. There seems to be a tendency for the reticulations to develop from the flagellar pore and sulcus to the left, around the body in the direction of the girdle, and also to the right, but less markedly (see Plate 9, fig. 2, 4, 7). The reticulations are not uniform in size or pattern, but have a very characteristic facies due to the prevalent tendency to form rectangles, especially along suture lines between the apical plates and at the precingular edge of the girdle. There are about twenty-five polygons between the girdle and apex along the midventral suture. The number of rows of polygons in any plate is less than in the closely related *H. curvatum*. The polygons each bear a central pore. Pores are also sparsely scattered over the non-reticulate areas and in the girdle.

The cell contents are unknown.

Dimensions: — Length, 249 (220–275) μ; transdiameter, 139 (128–160) μ; length of right antapical, 58 μ; of left antapical, 62 μ.

Variation: — There is a wide range in dimensions in our specimens. The maximum size (275 μ) was in a specimen from Station 4691 at a surface temperature of 73°, while one from 4724 at 79° measured only 220 μ. There is also some variation in the degree of curvature of the apical, the slenderness of the antapical horns, and the extent of the reticulations. Murray and Whitting's (1899) figure shows faint partial polygons in the girdle. One of our specimens had the proximal 0.25 of the girdle reticulate. Secondary polygons were seen in one specimen with wide intercalary zones.

Comparisons: — This is the largest, and the terminal species in the *H. dispar* group, and has the most specialized form as shown in curvature of the horns, elongation of the sulcus, fins on the sutures and sulcus, and modifications in the pattern of the reticulations. For comparisons with the nearly related *H. curvatum* see that species.

The type locality is the Carribean Sea between Jamaica and Colon (Murray and Whitting, 1899).

Occurrence: — *Heterodinium blackmani* is recorded (Plate 13) at eleven of the 127 stations. There are 1, 0, 1, 6, 3, and 0 stations respectively on the six lines of the Expedition. Of these eleven stations, one (4596) is in the Mexican Current, three (4691, 4697, 4699) are in the Easter Island Eddy, and seven (4701, 4705, 4706, 4707, 4732, 4734, 4739) are in the South Equatorial Drift. At two stations (4596, 4706) the species was taken in surface hauls. All other records are from hauls from 300–0 fathoms.

The temperature range of these eleven stations at the surface was 72°–84° and the average was 75.8°, a relatively high average.

The frequency is 1% only at Station 4707. At all other stations it is less.

This species has been reported previously by Murray and Whitting (1899) from eleven stations in the tropical Atlantic between 10°–25° N? and 44°–80° W. from April to December in temperatures of 70°–82°. Karsten (1907) reports it from five widely separated stations in the Indian Ocean between 7° N. and 30° S. and 85°–96° E. in hauls within fifteen meters of the surface, except one haul from 200–0 meters.

This is a eupelagic, not widely eurythermal, species of wide distribution in tropical seas. Our data in contrast with Karsten's (1907) suggest a relative infrequency in surface waters.

The *rigdenae* group

Plate **5**, fig. 1, 4; Plate **13**; Plate **15**, fig. 16–19; Plate **17**, fig. 42–47; Plate **18**, fig. 48–51

Epitheca in ventral view not contracted into an apical horn, or with extremely short horn, low and wide (not less than 80°); antapicals short and stout.

This group contains four species, *H. rigdenae* Kofoid, *H. crassipes* Schiller, *H. serippsi* Kofoid, and *H. trirostre* (Murray and Whitting). Only the first and third occur in the collections of the Expedition.

Heterodinium rigdenae Kofoid

Plate **5**, fig. 4; Plate **15**, fig. 16; Plate **17**, fig. 42–47

H. rigdenae Kofoid, 1906, p. 356-357, pl. 18, fig. 6-8; Karsten, 1907, p. 295.
H. longum Kofoid, 1907, p. 165, 183, pl. 7, fig. 44.
H. rigdunae, Karsten, 1907, p. 473.

Diagnosis: — A medium-sized angular species of pentagonal outline, oblique axis; dorsoventral diameter 0.6 transdiameter, length 1.6 transdiameters; epitheca erect, conical; antapical horns short, stout, subequal, flaring, pointed; surface irregularly reticulate. Length, 120 (110–135) μ. Rare in Eastern Tropical Pacific, California Current, Indian Ocean, and Mediterranean Sea.

Description: — This is a stout, quite angular species with the body in ventral view roughly pentagonal, and much flattened for the whole of its length which is 1.28–1.60 transdiameters. The dorsoventral flattening reduces that diameter to 0.6 the transdiameter. The epitheca in ventral view is a flattened cone (70°–90°), as a rule without apical horn, though in a few individuals there is a slight apical contraction differentiating a short horn not over the diameter of the apex in length. The sides are usually quite straight, though sometimes the right, or even both, may be slightly concave. In lateral view the apical horn is differentiated from the midbody by contraction at the apical-precingular suture. Basally in this view it is a low asymmetrical cone (90°), tilted dorsally with short, slightly convex dorsal, and longer, concave ventral slope. From this arises the stout conical (30°) apical horn with concave ventral, and convex dorsal side and squarely, or obliquely truncated apex.

The midventral suture is angled at the apical-precingular suture and meets the apex a little to the right of the middle. The ventral area is quadrangular with a reniform ventral pore with the concavity facing to the right almost midway between apex and girdle.

The hypotheca is slightly shorter than the epitheca, basally subconical (45°) with concave right and convex left margin and deep wide ventral excavation. In lateral view it is subconical (35°) with concave ventral and convex dorsal contour with an angle at the postcingular-antapical suture.

Distally it bears the two quite stout antapical horns. These are conical, the right 33°–50°, the left 40°–60°. The tips vary from acute to blunt, and sometimes have very small terminal spinules. They are deflected outwardly from the vertical, the right 15°–22°, the left 15°–32°. The right is sometimes curved outwardly. They vary greatly in length, the right being generally a bit the shorter. In very stout individuals the length is scarcely 0.20 transdiameter while in the more slender ones it attains 0.37 transdiameter. The width between tips is 0.38–0.65 transdiameter. The postmargin is asymmetrically concave, often tending towards a subangular (70°–90°) outline. Its depth is 0.18 to 0.30 transdiameter and there is no marginal list.

The girdle is submedian, tilted posteroventrally 15° from the horizontal, deflected posteriorly at the distal end a girdle width, and without any overlap. The precingular ridge is a stout angular projection with a heavy rim, but the postcingular is equally developed only in the proximal quadrant. Elsewhere it is reduced to a low ridge which almost vanishes in the distal quadrant. The furrow is asymmetrically impressed, deeper anteriorly, and fades out distally.

The sulcus is straight and narrow, its length being about 0.33 transdiameter. It lies towards the left side of the ventral depression and has no prominent lists. Its distal end invades the postsulcal depression for nearly half its width. This depression is guarded by high ridges developed on the midventral surfaces of the two antapicals.

The plates are, as a rule, very clearly marked out by narrow suture ridges which, as ecdysis approaches, expand into intercalary zones (Plate 5, fig. 4). The lateral interapical sutures bear low fins. Anterior intercalary 1^a is a triangular quadrilateral which often has a partial exposure on the ventral surface as well as the usual dorsal one. It is located a little below the second quarter of the left shoulder. Postcingular 7″′ is subtriangular, with an unusually wide base with the hypotenuse sloping towards the flagellar pore. It often lacks all reticulations.

The wall is reticulate, sometimes throughout, sometimes lacking these markings on the whole, or a part, of postcingular 7″′. The polygons are subregular with a tendency for considerable local irregularities in size. The mesh is prominent and the larger polygons are always porulate. In the girdle there are two

rows, the lower being the larger. Secondary non-porulate polygons appear along both sides of the widening intercalary zones as ecdysis approaches (Plate 5, fig. 4). There are twelve polygons along the midventral suture between apex and girdle and twenty across the dorsal side at the girdle.

The plasma is very hyaline and completely colorless, or it may contain a few irregular, or reniform, pale greenish-yellow chromatophores.

Dimensions: — Length, 118 (95–140) μ; transdiameter, 80 (60–94) μ; dorsoventral diameter, 55 μ; length of right antapical, 22 (15–25) μ; of left antapical, 26 (19–35) μ. The largest individual (140 μ) is that figured on Plate 5, fig. 4, which is in the stage preparatory to ecdysis. All others are 125 μ or less.

Variation: — The material of the Expedition is quite variable in size, in length, divergence and size of antapicals, and in shape of the postmargin. The figure (Plate 5, fig. 4) here published is unusual in that the thecal reticulations which include the secondary polygons on the intercalary zones, and the proportions, are distorted, mainly in length, by the expansion due to approaching ecdysis.

Comparisons: — *Heterodinium rigdenae* is much like *H. crassipes*, the second member of the group, in habitus and thecal surface, but differs in stouter, relatively wider body, much narrower and shorter ventral area, in the shorter sulcus not extending to the postmargin, and lack of overhang in the girdle. It differs from *H. scrippsi* in the absence of angles on the shoulders, less dorsoventral flattening, less development of fins on sutures, less angled ventral suture, and straighter sulcus. Of the species in the *expansum* group, it is most like *H. hindmarchii* in surface markings and antapicals, but is shorter, stouter, and has less elongation of epitheca and of antapicals.

Synonymy: — *Heterodinium longum* was described by Kofoid (1907a) from Stations 4732, 4734, and 4742. One of the specimens on which it was founded is figured in Plate 5, fig. 4. This figure shows wide intercalary bands along the suture lines. These bands were not shown in the figure of *H. longum* (1907a, pl. 7, fig. 44) accompanying the original description. Examination of the genus as a whole has led us to the conclusion that ecdysis rather than binary fission is prevalent in Heterodinium. We have concluded that *H. longum* is based on specimens approaching ecdysis, and therefore somewhat more elongated, due to expansion resulting from the growth of the transverse intercalary zones, and had secondary reticulations spreading over these zones. We therefore reduce *H. longum* to a synonym of *H. rigdenae*.

The type locality is in the California Current off San Diego, California (Kofoid, 1906a).

Occurrence: — *Heterodinium rigdenae* is recorded (Plate **13**) at twenty-three of the 127 stations, the maximum record for the genus. There are 3, 6, 1, 5, 7, and 1 stations respectively on the six lines of the Expedition. Of these stations two (4580, 4583) are in the Mexican Current, three (4613, 4637, 4638) are in the Panamic Area, four (4647, 4650, 4659, 4664) are in the Peruvian Current, four (4691, 4695, 4697, 4699) are in the Easter Island Eddy, one (4715) is in the Galapagos Eddy, eight (4701, 4717, 4724, 4730, 4732, 4734, 4737, 4739) are in the South Equatorial Drift, and one (4742) is in the South Equatorial Current. No specimens were taken in surface hauls. It was taken at two stations (4724, 4732) in hauls from 800–0 fathoms, and at Station 4732 and the twenty-two others in hauls from 300–0 fathoms.

The temperature range at these twenty-three stations was 68°–83° and the average was 75.8°, rather a high average. Of the twenty-three records, seventeen are between 75° and 83°.

The frequency at three stations (4695, 4724, 4737) is 1%; at the other twenty it is less. Twenty-six specimens were seen.

Heterodinium rigdenae was described by Kofoid (1906a) from the California Current off San Diego where it was taken in June in hauls from 90 to 100–0 fathoms, but never in the numerous surface collections made in that region. It is absent from the surface collections of Murray and Whitting (1899) from the tropical Atlantic. Karsten (1907) reports a specimen from the Indian Ocean near the Seychelles Islands in a haul from 200 m.

This is a eupelagic, widely eurythermal species from the subsurface of tropical and warm-temperate seas. Its occurrences in the Peruvian and California Currents are suggestive of a wide distribution in warm temperate currents, and the large number of record stations and the frequency records of 1% indicate that it is among the most abundant and widely distributed representatives of this sparsely represented genus.

Heterodinium scrippsi Kofoid

Plate **5**, fig. 1; Plate **15**, fig. 18; Plate **18**, fig. 48–51

Heterodinium scrippsi Kofoid, 1906a, p. 342, 344, 345, 347, 351, 359–360, pl. 17, fig. 1–5, Fig. A, B; Karsten, 1906, p. 187, 194; 1907, p. 419, 450, 471; Lindemann, 1928, p. 95–96, fig. 82.

Peridinium areolatum Karsten, 1906, p. 150, pl. 23, fig. 18a, b; p. 150, footnote, Karsten states "=*Heterodinium scrippsi* Kofoid".

Diagnosis: — A medium-sized species of robust, angular habit; length, 1.5 transdiameters; epitheca considerably larger than hypotheca with slightly emer-

gent horn; anterior intercalary near girdle facing on precingular 3″; sulcus not over 0.5 distance from girdle to postmargin; sutures often with ribbed lists, ventral pore at anterior end of ventral area. Length, 130–155 μ. Eastern Tropical Pacific, California Current, and tropical Atlantic.

Description: — This is a medium-sized to large species with very robust but angular facies. Its length is 1.4–1.5 transdiameters. The dorsoventral diameter is 0.6 transdiameter. The ventral view is heptangular but the lateral reveals the broadly bulging midbody on the dorsal margin. The epitheca is distinctly larger than the hypotheca, its length being 1.4 that of the hypotheca and its lateral expansion relatively greater. The epitheca in ventral view is pentagonal, its length 0.75–0.80 transdiameter. Its lateral outlines are marked by symmetrical or subsymmetrical expansions at 0.3 of the distance from the apex to the girdle in rounded shoulders so that the apical area has the lateral contour of a cone of approximately 90°. The right shoulder is usually a little more angular than the left. Below this level it narrows to about 40° and flares abruptly at the girdle, more on the left than on the right side. In lateral view the two faces are very different. The ventral is flattened and excavated like a scoop. The dorsal is concave, flaring below the apical-precingular suture into the dorsally globose midbody. The asymmetrical apical horn thus set off is recurved dorsally and is roughly subconical (45°), flaring basally into the midbody. The apical horn is slightly emergent in ventral view, but its length scarcely equals the diameter of the squarely truncate apex.

The midventral suture is a narrow tract with a slight deflection to the left at the oblique rectangular ventral area located immediately below the middle of the epitheca. The ventral pore is subcircular, or broadly reniform with the concavity directed anteriorly.

The hypotheca in ventral view is subconical (50°) with concave right and convex left outline. In lateral view it is subhemispherical dorsally and deeply depressed in the sulcal region ventrally. Its length is 0.65 transdiameter.

The antapical horns are short, stout, conical, sharp pointed, and unequal. The right is the smaller, 0.2 transdiameter in length, a symmetrical cone (30°), and deflected to the right 15° from the vertical. The left is stouter (45°–55°), less deflected (7°), and longer (0.35 transdiameter in length). The postmargin is very asymmetrically concave, deepest at the right, and generally bears a coarsely reticulate and ribbed fin. The distance between the tips is 0.4–0.5, and the depth of the indentation 0.18–0.20 transdiameter.

The plates are clearly marked, either by a narrow raised rib somewhat

heavier than the adjacent mesh, or by this and an expanding intercalary zone along one side of the rib, usually the median or the anterior side. In some specimens the ribs bear a low fin into which adjacent bars of the reticulum are extended as tapering riblets. These fins first appear on the lateral interapical sutures, the postmargin, and later on other vertical sutures along stream lines parallel to, or not opposed to the axis of progression. The anterior intercalary is exposed wholly on the dorsal side. It is unique in the genus in being much more widened at the mesial, usually quite narrow, end. The widening is not quite enough to make the plate rectangular, but it does take up nearly 0.5 of the left side of precingular 3″. Postcingular 7‴ is an elongated, rather irregular plate, nearly twice as long as wide, and not much contracted in the girdle. It is free from reticulations in all specimens thus far seen.

The surface is rather coarsely and heavily reticulated, with porulate polygons of subuniform size, smallest at the girdle, generally pentagonal, with a tendency to quadrilateral form near sutures. There are 10–12 between girdle and apex along the midventral suture, fifteen along the middorsal region, and twenty-three along the dorsal side of the precingular ridge. Secondary polygons have been seen only in a few individuals along a few of the sutures.

The cytoplasm and the whole organism are very transparent. The ellipsoidal nucleus lies near the flagellar pore. Adjacent to this are a few, small, subspherical, pale greenish chromatophores.

Dimensions: — Expedition specimens: length, 140 (135–145) μ; transdiameter, 97.5 (95.0–100.0) μ; length of right antapical, 16 (15–17) μ; of left antapical, 27.5 (25–30) μ. San Diego specimens: length, 140–155; transdiameter, 100–105 μ; dorsoventral diameter, 60 μ; length of right antapical, 20 μ; of left antapical, 26 μ. The magnification of the figures of the San Diego specimens (see Kofoid, 1906a, p. 364, pl. 17, fig. 1) is incorrectly given due to a typographical error. It is 425, not 725 as stated.

Variation: — Specimens from the Expedition collections vary in the degree of rounding off of the lateral angles of the epitheca, in the extent of inequality of the antapicals, in the numbers of polygons in given plates, and in the extent of development of the fins along the sutures. Variations due to approaching ecdysis affect the width of intercalary bands, the number of secondary polygons along these zones, and the proportions of the body.

Material from San Diego (near Station 4571) is somewhat larger and more heavily reticulated than that of the Expedition.

Karsten's (1906, pl. 23, figs. 18a, b) figures are crudely drawn showing only

a few of the suture lines. It appears that his ventral view (his figure 18b) represents the dorsal side (of the epitheca only) drawn as though it were the ventral, an accident happening easily on a tilted specimen. The shoulders, in his ventral view, are more rounded than in any of our material.

Comparisons: — This species is near the end of a side line, which we have called the *rigdenae* group, which leads off from the *dispar* series and is differentiated from that series by the stouter body, low conical, or angled epitheca, and shorter antapicals. The angled shoulders differentiate *H. scrippsi* from the others in the *dispar* and *rigdenae* groups, and, in fact, from all species of the genus except *H. angulatum* of the globose *expansum* series. The latter species has more widely set, stouter, equal antapicals. *H. scrippsi* attains a high degree of pronounced reticulation and development of ribbed lists.

Synonymy: — *Heterodinium scrippsi* is the type species of the genus by the author's designation. Karsten (1906) had discovered it in the collections of the "Valdivia" and had called it *Peridinium areolatum*. He utilized Kofoid's name for the species in his lists of species at stations but unfortunately published his own manuscript name in the explanation of his plate.

The type locality is in the California Current off San Diego, California (Kofoid, 1906a).

Occurrence: — *Heterodinium scrippsi* is recorded (Plate **13**) at ten of the 127 stations. These are widely scattered over the area explored by the Expedition, there being 1, 1, 1, 3, 4, and 0 stations on the six lines. Of these ten stations, one (4580) is in the California Current, one (4637) is in the Panamic Area, five (4681, 4701, 4732, 4736, 4739) are in the South Equatorial Drift, and three (4691, 4695, 4697) are in the Easter Island Eddy. The species was never recorded in surface hauls. At all ten stations it was taken in hauls from 300–0 fathoms and at Station 4732 was taken also in a haul from 800–0 fathoms.

The frequency was 1% only at Station 4580. At the other nine it was less than this.

The temperature range at the ten stations at the surface was 68°–81° and the average was 76.1°.

This species was taken by Kofoid (1906a) off San Diego, near Station 4571, in hauls from 95 fathoms in June. It was one of the commoner species of the genus taken off San Diego, but was never abundant, only single individuals, as a rule, being observed in any haul.

Karsten (1906) records it at two stations only of the "Valdivia" cruise. These are at 6° N., 15° W. and 3° N., 3° W. west of the Gulf of Guinea in Septem-

ber, in hauls from 200 m. He regards the species as a member of the "Schattenflora." He also reports (1907, p. 471) it from the Indian Ocean.

This species is eupelagic in warm-temperate and tropical waters from deeper levels of the light zone, and is moderately eurythermal, and, like others of the genus, is never abundant. The fact that only a single record attained 1% is indicative of its relative infrequency.

Subgenus Platydinium Kofoid

Plate 14; Plate 16, fig. 26–40

Platydinium Kofoid, 1906a, p. 351; Lindemann, 1928, p. 96.

The body is much flattened dorsoventrally. The epitheca is scoop-like with the apex broadly and evenly rounded in ventral view; antapical horns are well developed, though one of the two is suppressed in each of two species.

The type species of the subgenus Platydinium was not designated by Kofoid (1906a). As described by him this subgenus included only *H. scrippsi* and *H. whittingae*. Since *H. scrippsi* is now the type species of both the genus and subgenus Heterodinium and is in this paper included in that subgenus, *H. whittingae* becomes, and is here designated as, the type species of the subgenus Platydinium.

This subgenus contains two groups, the *pavillardi* group without sinistral lobe with eight species (Plate 16, fig. 26–33) and the *gesticulatum* group with the sinistral lobe and with six species (Plate 16, fig. 34–40).

Key to the species of the subgenus Platydinium Kofoid

1. Epitheca nearly bilaterally symmetrical, antapicals balanced in size and position . . . . . 2.
1. Epitheca symmetrical or asymmetrical, antapicals unequal in size and deflection . . . . . 3.
2. Antapicals stout, incurved . . . . . *whittingae* Kofoid.
2. Antapicals more slender, spreading . . . . . 4.
4. Epitheca with deep precingular constrictions . . . . . 5.
4. Epitheca with shallow precingular constriction, convex above . . . . . *agassizi* Kofoid.
5. Epitheca subangular anteriorly, antapicals not over 0.5 transdiameter long . . . . . *fides* Kofoid.
5. Epitheca flattened semicircular anteriorly, antapicals about 1 transdiameter long. . . . *scotti* sp. nov.
3. No sinistral lobe or denticles on hypotheca . . . . . 6.
3. With sinistral lobe, or with left horn suppressed . . . . . 7.
6. Postmargin horizontal, apical pore very much deflected to right . . . . . 8.
6. Postmargin not horizontal and straight . . . . . 9.
8. Antapicals subvertical, length of body, 85 μ. . . . . *pavillardi* nom. sp. nov.
8. Antapicals incurved, length of body, 140 μ. . . . . *laticinctum* Kofoid.
9. Right antapical not over 1.5 girdle width in length, much smaller than the left . . . . . 10.
9. Right antapical 3 girdle widths in length . . . . . *laeve* Kofoid and Michener.
10. Left antapical 0.3 transdiameter in length, conical . . . . . *asymmetricum* sp. nov.
10. Left antapical 0.4 transdiameter in length, abruptly pointed . . . . . *inaequale* Kofoid.
7. One antapical suppressed . . . . . 11.

7.	Both antapicals present	12.
11.	Right antapical suppressed	*deformatum* (Kofoid).
11.	Left antapical suppressed	*sinistrum* Kofoid.
12.	Right antapical distally recessed on median face	*extremum* (Kofoid).
12.	No distal recess on right antapical	13.
13.	Both antapicals deflected to the right	*varicator* sp. nov.
13.	Antapicals not deflected to the right	14.
14.	No denticles at postcingular-antapical suture on sinistral lobe	*gesticulatum* Kofoid.
14.	One to three denticles on sinistral lobe	*mediocre* (Kofoid).

The *pavillardi* group

Plates **10**; **11**; **14**; **18**, fig. 52–55; Plate **19**, fig. 56–58

This group is characterized by the entire absence of the sinistral lobe and the accompanying compensatory shrinkage of the right margin of the hypotheca to a concave margin. There are no denticles at the postcingular-antapical suture. Both antapicals are always present.

This series includes eight species, of which the first is *Heterodinium pavillardi* nom. nov. Pavillard (1916), described *Heterodinium kofoidi* from the Gulf of Lyons but this specific name had been used a short time previously by Schiller (1916) for another species of Heterodinium from the Adriatic. Consequently the name *H. pavillardi* is substituted by us. The other species of this group are *H. asymmetricum* sp. nov., *H. inaequale* Kofoid, *H. laeve* Kofoid and Michener, *H. agassizi* Kofoid, *H. whittingae* Kofoid, *H. laticinctum* Kofoid, and *H. fides* Kofoid. With the exception of *H. pavillardi* from the Gulf of Lyons and *H. inaequale* from the California Current off San Diego, all species of this series occur in the collections of the Expedition.

Heterodinium agassizi Kofoid

Plate **10**, fig. 4–8; Plate **16**, fig. 27

Heterodinium agassizi Kofoid, 1907a, pp. 164, 178, pl. 6, fig. 35.
Peridinium venter Hensen, 1911, p. 174, fig. C 7, Tab. XVI.
Heterodinium Agassizi Hensen, 1911, p. 174.

Diagnosis: — A large species with an elongated symmetrical body, narrowly ovate in outline, except for the postindentation; length, 2.1 transdiameters; epitheca 1.2 transdiameters in length in ventral view, with semicircular apical outline, slightly constricted above girdle, scoop-shaped; girdle with both lists narrow; postsulcal trough narrow; antapicals straight, subequal, 0.5 transdiameter in length; ventral suture straight, ventral area elongated; surface completely and heavily reticulated, twenty-eight polygons along precingular rim. Length, 160 μ. Rare in Peruvian Current, Easter Island Eddy, South Equatorial Drift of Pacific and Equatorial Currents and Sargasso Sea of Atlantic.

Description: — This species is noteworthy for its elongated, relatively narrow, scoop-shaped body, and lack of asymmetry. Its length is 2.01 transdiameters at the girdle. The epitheca and hypotheca are subequal in length at the midlateral line. Ventrally, the former is 1.3 the extreme ventral length of the latter; dorsally, the hypotheca is 1.75 the length of the epitheca. The epitheca in ventral view has a semicircular outline in its anterior 0.5, and halfway between this and the girdle constricts at the apical-precingular suture, to 0.94 the diameter at the precingular list. The concavity is deeper on the right than on the left. The epitheca is widest at about 0.3 of its length from the apex where it is 1.1 transdiameters wide. In lateral view both faces are concave, the dorsal equally throughout, the ventral more in its posterior 0.66 than in the anterior. It is broadly hollowed out into a shallow scoop-like shape. The epitheca is thus quite thin anteriorly, its outline embracing an angle of 20° apically, increasing to 70° basally, with the flare at the girdle. The apical pore is level with the margin and lies symmetrically in the major axis. The midventral suture is vertical and nearly straight. The ventral area is in the center of the epitheca above the transverse suture and has the very unusual form of a long narrow tract whose length is six times its width. The ventral pore is at its anterior end, and is broadly reniform with a shallow indentation, directed to the right.

The hypotheca in ventral view is subconical (25°) in outline with nearly straight sides, the right a bit convex. In lateral view it has a subconical outline (50° basally, decreasing to 15° towards the antapex), with concave sides passing into the slightly tapering horns which contract to the pointed tips more abruptly in this than in the ventral view. It is deeply depressed in the narrow, median sulcal tract. This is only 0.2 transdiameter wide at the girdle, widens to 0.3 at the postmargin, curves to the left in its anterior half, and becomes more nearly vertical posteriorly.

The antapical horns are very nearly equal in length and proportions. They are conical (32°), with straight sides, and vertical. The right in some specimens has a bit of outward deflection. Their length is 0.44, the distance between tips 0.44, and the depth of the indentation 0.44 transdiameter, respectively. The indentation embraces an angle of 45° and its bottom forms the almost symmetrically rounded, very short, concave postmargin about 0.1 transdiameter wide. No fin was found on the postmargin.

The girdle is submedian, is tilted posteroventrally 25°, and is relatively very narrow, being only 0.06 transdiameter wide. It is quite uniform throughout, is displaced distally only its own width, and is without distal overlap. The pre-

and postcingular rims are equally developed as projecting angles. The furrow is impressed about 0.5 its width, more deeply anteriorly.

The sulcus is long, 0.4 transdiameter in length, extending 0.9 the distance from girdle to postmargin, very narrow, nearly straight, deflected 10° to the left from the vertical, and has only a low ridge on either side. It almost crosses the postsulcal region which is deep and narrow, being less than 0.25 transdiameter in its widest part.

The plates are marked by low ridges scarcely differentiated above the heavy reticular mesh, becoming prominent only when expanded by secondary polygons. Intercalary plate 1^a is triangular, exposed only in dorsal view, fills nearly 0.8 of the lower third of the left shoulder, and crowds precingular 2″ into a narrow rectangular plate scarcely as wide as the adjacent girdle. Postcingular 7‴ is a rectangular plate, over twice as long as wide, not contracted in the girdle. A spear-shaped platelet in the bottom of the sulcus runs towards the flagellar pore from its anterior end which is revealed when the plates are parted. It is not known whether this belongs to 7‴ or to the sulcus whose finer elements are unknown.

The surface is everywhere reticulated (except the ventral area) including the girdle and postcingular 7‴ which in so many species remains perfectly smooth. The polygons are coarsely porulate, remarkably uniform in size and in weight of the rather heavy reticular bars, though smaller near the girdle and on the antapicals. There are nineteen polygons along the midventral suture between apex and girdle, thirteen in the corresponding dorsal region, twenty-six at the precingular rim, and over thirty in the girdle on the dorsal side. There are two rows in the girdle but the anterior one is reduced in size. Secondary polygons appear in some suture lines, but no intercalary zones have been seen. Serrate lists were seen on the lateral interpostcingular sutures on one individual.

The theca and cytoplasm in life are translucent. Bright cadmium yellow chromatophores were observed in one specimen.

Dimensions: — Four individuals measured. Length, 161 (155–172) μ; transdiameter, 80.5 (75–88) μ; dorsoventral diameter, 65 μ; length of right antapical horn, 39 (35–50) μ; of left antapical horn, 39 (35–50) μ; width of girdle, 6.8 (5–10) μ.

Variation: — Specimens from the Expedition collections are quite uniform in the epitheca but vary more in the antapicals. In one large specimen (172 μ) from Station 4737 the antapicals were very long (50 μ, 0.6 transdiameter) and more slender than in other specimens. A specimen from Station 4657 had a much wider girdle (10 μ) and more oblique antapicals.

Hensen's (1911) figure of this species (as *Peridinium venter*) is sketchily made and inverted. It differs from our specimens in a much narrower indentation and shorter postmargin, less smoothly rounded apical contour, and is drawn with indications of a very unusual amount of distal displacement of the girdle.

Comparisons: — *Heterodinium agassizi* stands somewhat alone in the subgenus Platydinium. It has the rounded epitheca of *H. pavillardi*, *H. inaequale*, *H. asymmetricum*, and *H. laticinctum*, but has equal instead of unequal antapicals and a heavily reticulated instead of a smooth surface, characters which the group just cited all lack. It has more in common with *H. whittingae* in its close-set antapicals and reticulate surface, but differs from it in more slender body, and in the lateral constriction of the epitheca. In this constriction, as well as in the equal antapicals, it approaches *H. fides*, but has less constriction, more rounded apical region, and less flaring antapicals. It is a sort of transition form between the smaller and simpler species and, in two directions, namely toward *H. whittingae* and *H. fides*, towards more diversified ones.

Synonymy: — Hensen (1911) publishes a very imperfect and inverted figure which he names *Peridinium venter* with the added statement "scheint mit *Heterodinium Agassizi* identisch zu sein." The girdle is incompletely shown, but with indications of great displacement. The antapicals are very long and narrow and the indentation very much narrower. The apical region is also more squarish and the constriction lower down. The divergences from our material are so great and significant that we are skeptical as to the identity of his species with *H. agassizi*, but, in the absence of critical evidence as to the structure of his specimens, leave the matter in suspense pending a reëxamination of Atlantic collections.

The type locality is Station 4699 in the Easter Island Eddy.

Occurrence: — *Heterodinium agassizi* is recorded (Plate **14**) at seven of the 127 stations. There are 0, 1, 2, 3, and 1 record stations on the six lines of the Expedition. Of these seven stations, one (4657) is in the Peruvian Current, two (4691, 4699) are in the Easter Island Eddy, and four (4681, 4701, 4709, 4737) are in the South Equatorial Drift. All specimens were taken in hauls from 300–0 fathoms.

The temperature range at these seven stations at the surface was 68°–81.5° and the average was 72.9°.

The frequency was 1% at Station 4657, and less than that at the other six stations. Two specimens were recorded at Station 4699.

The species is confined in our collections to deeper hauls in the Peruvian Current and water derived largely from it, and the average temperature (72.9°) is low.

Hensen (1911) reports as *Peridinium venter* a species of Heterodinium which is doubtfully *H. agassizi*. He records it at fifty stations with a computed total of 788 specimens. These stations were widely distributed throughout the tropical Atlantic in the North (6) and South Equatorial (16) Currents, the Gulf Stream Drift (1), Guinea (7), Florida (3), Canary (4), and Brazilian (4) Currents, and Sargasso Sea (9).

This species is eupelagic, confined to deeper levels, and, in the Pacific, mainly confined to the cooler areas of the South Equatorial Drift and Easter Island Eddy. This stenothermal limitation is not borne out by the distribution of Hensen's species, doubtfully referred here.

Heterodinium fides Kofoid

Plate **11**, fig. 2, 4, 6; Plate **16**, fig. 28; Plate **19**, fig. 56–58

Heterodinium fides Kofoid, 1907a, p. 165, 177, 179, 180, pl. 7, fig. 45.

Diagnosis: — A medium-sized species, almost symmetrical; length, 1.5 transdiameters; epitheca scoop-shaped, with deep bilateral constrictions; hypotheca contracted; antapicals subequal, spreading; girdle slightly oblique, furrow present, postcingular rim partly developed; anterior intercalary very large; surface reticulated. Length, 120–125 μ. Rare in the South Equatorial Drift of the Eastern Tropical Pacific.

Description: — This is a very unique species in the genus with body and antapicals subsymmetrical and deeply constricted epitheca. The epitheca and hypotheca are subequal in length, but the epitheca has the greater volume. The epitheca is scoop-shaped, being deeply hollowed-out ventrally. In ventral view its length is 0.75 transdiameter. It is deeply constricted at the two sides at about the level of the apical-precingular suture, contracting to 0.67–0.73 transdiameter, at 0.66 the distance from the apex to the girdle. The bay on the left side is a bit higher up than the one on the right and its flare to the girdle a little steeper than on the right. Anteriorly the epitheca expands asymmetrically at about 0.25 transdiameter below the apex to about 0.95 transdiameter. The apex subtends an angle of 110°–120° with slightly convex sides, and flares towards the girdle at about 65°. The apical pore is median but tilted dorsally. The midventral suture is angled at the apical-precingular junction and deflected to the left. The ventral area is elongated, located just a little below the middle of the epitheca, and has a broadly reniform ventral pore near its anterior end. In lateral view the dorsal outline is concave, the apical region being deflected dor-

sally 15°. The ventral outline is convex anteriorly and deeply concave posteriorly in midventral view.

The hypotheca is 0.82–0.86 transdiameter in length, in ventral view having the outline of a cone of about 85° basally, with subequal concave sides, deeper on the right. Distally the sides become parallel and flare slightly in the distal parts of the antapical horns. In lateral view the outline is subconical (75°), with an angle dorsally at the postcingular-antapical suture, and a deep midventral excavation.

The antapical horns are subequal, the left a bit stouter than the right, subconical (right 15°–20°, left 25°–30°), pointed, and spread laterally distally 25° and 20° from the vertical. The postindentation is 0.30–0.45 transdiameter in depth and the distance between tips 0.45–0.60 transdiameter. The postmargin is abruptly concave, deepest at the right, and bordered by an irregularly denticulate fin.

The girdle is tilted posteroventrally 10°, displaced at its distal end posteriorly its own width, and has no overlap. It is quite wide, 0.12 transdiameter across, with well-developed pre- and postcingular ridges, the latter fading out in the distal quadrant. These ridges are angular projections without fins. The furrow is indented 0.5 its width but fades out distally.

The length of the sulcus is 0.75 the distance from the precingular rim to the postmargin, convex to the left, narrow, with heavy borders. It invades the concave postsulcal trough for half its length.

The plates are clearly marked by heavy ribs at the sutures. The anterior intercalary is subquadrangular and not visible in the ventral view. The length of postcingular 7″′ is nearly twice its width and it is rounded posteriorly. The surface is heavily reticulated throughout, except on postcingular 7′″ which is smooth with a single line of pores. The girdle has two subequal rows of polygons. There are fourteen polygons along the midventral suture in the epitheca and about twenty-five on the dorsal side anterior to the girdle. The polygons are fairly uniform in size with only a few exceptionally large ones. No secondary polygons at sutures have been seen.

The cell contents are unknown.

Dimensions: — Two specimens measured. Length, 120–125 μ; transdiameter, 70–83 μ; length of right antapical, 27–33 μ; of left, 25–28 μ.

Variation: — The main variations noted in our limited material are in the depth and inequality of the constrictions of the epitheca, flare of the antapicals, and depth and shape of the postmargin.

Comparisons: — *Heterodinium fides* is unique in the genus in having the deep lateral constrictions of the epitheca. In other particulars, notably in the hypotheca, flare, shape and symmetry of the antapicals, and in the character of the reticulations, it is closest to *H. agassizi*.

The type locality is Station 4728 in the South Equatorial Drift.

Occurrence: — *Heterodinium fides* is recorded (Plate **14**) at five of the 127 stations. There are 0, 0, 0, 1, 4, and 0 stations on the six lines of the Expedition. All five (4707, 4724, 4728, 4732, 4736) are near the center of the South Equatorial Drift. It was not taken in surface hauls. All records are from hauls from 300–0 fathoms.

The temperature range at these five stations was 72°–81° and the average was 77.6°.

This species is cupelagic, stenothermal at the higher temperatures, and confined to deeper levels.

Heterodinium whittingae Kofoid

Plate **16**, fig. 29

Heterodinium whittingae Kofoid, 1906a, pp. 343, 344, 346, 349, 351, 361, 362, pl. 19, figs. 11–14.

Diagnosis: — A very large species, body dorsoventrally much flattened, ellipsoidal in outline in ventral view, notched on the left posterior margin; length 1.4 transdiameters; epitheca and hypotheca subequal; girdle very oblique and very narrow; antapicals short, stout, incurved; anterior intercalary triangular; ventral area minute; surface completely and unevenly reticulated. Length, 180 μ. Eastern Pacific in California and Peruvian Currents, Galapagos Eddy, and South Equatorial Drift.

Description: — The body in ventral view is broadly elliptical, its length being 1.4 transdiameters. The elliptical outline is interrupted by the slightly emergent apical pore, projecting girdle, the sharp notch on the left posterior arc where the postcingular plate 2′″ overhangs antapical 2″″, and the postindentation. The body is very much dorsoventrally flattened, its diameter in that axis being only about 0.5 transdiameter, or less, according to the amount of tilting. The oblique diameter in the plane of the girdle is nearly 0.66 transdiameter. This flattening, with the accompanying hollowing-out of the midventral region, gives a scoop-shaped form to the body, especially to the epitheca. The length of the epitheca in ventral view is 0.58 of the total length and 0.8 transdiameter. Its lateral outlines are symmetrically convex, with a little flare near the girdle. In lateral view

both faces are concave, the ventral more than the dorsal. The apical region is very thin due to the flattening, and the apical pore is carried over a little on the dorsal side where it is slightly emergent. The midventral line shifts to the left about 0.1 transdiameter at the ventral area which is midway between apical and flagellar pores. The area is scarcely differentiated from the junction of the suture lines. It contains a centrally located, very minute, elongated, reniform ventral pore.

The hypotheca in ventral view is 0.42 of the total length and 0.53 transdiameter. Its sides are more convex than those of the epitheca and less nearly equal, the right being shorter and more convex, and the left having a projecting tooth or a notch at the postcingular-antapical suture. In lateral view it is subconical (about 25°), flaring near the girdle. The ventral surface is depressed midventrally and the dorsal lacks the abrupt inset below the postcingular-antapical suture so prominent in such species as *H. spiniferum.*

The antapicals are subequal, very stout, subconical, the right in ventral view 55°, the left 45°, bluntly pointed, and incurved, their outer contour convex, the inner straight and vertical. They are close-set, their tips being only 0.14 transdiameter apart. The right is the shorter, 0.16 transdiameter in length, and the left, 0.21. The depth of the postindentation is 0.21 and its width 0.10 transdiameter. The postmargin is rounded and inclined to the right.

The girdle is very narrow, 0.05 transdiameter in width, widening to 0.14 in its distal quadrant. It is a bit sinuous, is guarded by very heavy but low pre- and postcingular ridges, is displaced at its distal end its own proximal width, and has no overlap. The furrow is scarcely impressed into the body wall.

The sulcus is short, extending scarcely 0.5 the distance from flagellar pore to tip of antapicals, and invading the postsulcal trough only a short distance. It is bordered by heavy ridges, but no lists, and contracts distally.

The plates are set off by clearly defined suture ribs, except the girdle plates and plate 7′ ″ which, in the spread of the distal end of the girdle, is included without a rib between itself and the adjacent girdle plate. Anterior intercalary 1^a is a small triangular plate exposed on both dorsal and ventral faces, but mainly on the former. Postcingular 7′ ″ is incorporated in the expanded distal end of the girdle. The surface is reticulated throughout, including the girdle and a part of postcingular 7′ ″. The region of this plate adjacent to the flagellar pore is porulate but not reticulated. The polygons are quite uneven in size, the smaller ones being found along the girdle and anterolateral and posterolateral sutures. All are porulate. No secondary reticulations at the sutures have been seen. There

are nineteen polygons along the midventral suture and 25–30 along the dorsal side of the precingular list. The girdle has 1–2 rows proximally and 2–3 in the distal quadrant.

The cytoplasm is very hyaline, fills only a part of the theca, and is much vacuolated. The very small sphaeroidal nucleus is centrally located and is scarcely 0.09 transdiameter across. One small pale-yellow chromosphere about the size of the nucleus lies near it.

Dimensions: — Length, 180 μ; transdiameter, 135 μ; dorsoventral diameter, 70 μ; obliquely along girdle, 82 μ; length of right horn, 25 μ; of left, 30 μ; diameter of nucleus, 12 μ.

Comparisons: — *Heterodinium whittingae* is near *H. laticinctum*, resembling it in epitheca, oblique girdle, and incurved antapicals, but differs from it in being reticulated instead of smooth, having equal instead of unequal antapicals, and a narrow, instead of wide, postindentation. It is also larger and longer. The projection on the left posterior margin is prophetic of the extensive development of that particular region in *H. gesticulatum*. The right anterior region is likewise slightly fuller than the left, as in the latter species.

The type locality is off the San Diego Coast, California.

Occurrence: — *Heterodinium whittingae* is recorded (Plate **14**) at eleven of the 127 stations. There are 1, 3, 3, 3, 1 and 0 stations on the six lines of the Expedition. Of these eleven stations, one (4583) is in the Mexican Current, two (4634, 4638) are in the Panamic Area, one (4648) is in the Peruvian Current, one (4691) is in the Easter Island Eddy, one (4715) is in the Galapagos Eddy, and five (4683, 4689, 4701, 4709, 4717) are in the South Equatorial Drift. No specimens were taken in surface hauls. It was taken at Stations 4689 and 4701 in hauls from 800–0 fathoms and at 4701 and the nine remaining stations in hauls from 300–0 fathoms.

The temperature range at the eleven stations at the surface was 70°–83° and the average was 74.4°.

The frequency at Station 4634 in the Panamic Area in a haul from 300–0 fathoms was 2%, at Stations 4691 and 4701 in the Easter Island Eddy and 4715 in the Galapagos Eddy it was 1%, all three in hauls from 300–0 fathoms. At the remaining seven stations and also at 4701 at 800–0 fathoms it was less than 1%.

Kofoid (1906a) described this species from the California Current in a haul from 85 fathoms off San Diego in July.

This species is eupelagic, eurythermal, limited to the deeper levels, and is rather widely distributed in the tropical and warm-temperate Pacific. Its fre-

quency is relatively high and its hyalinity, small amount of cytoplasm, small chromatophore, and flattened shape are all suggestive of a deep habitat.

Heterodinium laticinctum Kofoid

Plate 10, fig. 3; Plate 16, fig. 30; Plate 18, fig. 52–55

Heterodinium laticinctum Kofoid, 1907a, p. 165, 182, pl. 7, fig. 46.
Peridinium dentatum Hensen, 1911, p. 174, fig. C, 16, Tab. XVII.

Diagnosis: — A large robust species with very broad and very oblique girdle; length, 1.5 transdiameters; epitheca semicircular in outline; antapical horns incurved, unequal, the left 0.25 transdiameter long; postmargin horizontal, straight; postcingular rim present; surface smooth, pores numerous. Length, 140 μ. Rare in South Equatorial Drift of Eastern Tropical Pacific and Tropical Atlantic.

Description: — This is a very robust and very asymmetrical species. Its robustness is due to the broadly rounded epitheca and its asymmetry to the very oblique girdle and unequal incurved antapicals. Its ventral outline, barring the gap between the antapicals, is like that of a hen's egg, interrupted midway by the indented oblique girdle. Its length is 1.5 transdiameters. The epitheca is smaller than the hypotheca. Its length at the lateral margin is 0.40, in ventral view is 1.45, and in dorsal 0.15 that of the hypotheca. In ventral view the anterior outline is almost a perfect semicircle extending the curve a little as it nears the girdle. The apical pore is a bit depressed in the margin, deflected a little to the right (see ventral view, Figure 30) and is very small. In lateral view the appearance is very different. The apical region is dorsally reflexed so that the lateral interapical sutures are carried over into a dorsal exposure. The outline of the epitheca in this view fills an angle of 70°. The ventral slope is almost flat, with a midventral and a transverse depression at the apical-precingular suture. The dorsal contour is deeply and regularly concave, becoming steeper towards the apex.

The hypotheca in ventral view continues the ovate curve of the epitheca, but contracts asymmetrically more rapidly on the right than on the left side, so that the former is more convex. The sides, if straight, would make an angle of 45°. In lateral view the outline is very angular at the postcingular-antapical suture, more so dorsally than ventrally. The ventral face is flattened, concave, but interrupted by the projecting suture, and rather deeply depressed midventrally. Dorsally the outline is rapidly contracted and concave below the girdle and flattens out in the distal 0.66 of the distance between girdle and antapical

suture. At this suture it turns almost at a right angle ventrally in a concave contour to the tip of the ventrally deflected antapicals. The postcingular zone in the main makes an angle of 35°.

The antapical horns are rather slender, tapering regularly to a sharp point, unequal, and incurved. The right is about 0.5 the length of the left, conical (35°), and 0.14 transdiameter in length. The left is also conical (25°), and 0.28 transdiameter in length. The inner contours of the two horns are almost vertical and the postmargin horizontal and straight, except in the abruptly rounded angles. It bears an irregularly toothed, rather wide fin. The depth of the indentation is 0.20, and the distance between tips 0.31 transdiameter.

The girdle is unusually well developed in this species, perhaps better than in any other species in the whole genus. Both pre- and postcingular rims are developed, the furrow is indented, it is unusually wide (12 μ, 0.13 transdiameter in width), its plates are clearly outlined by heavy bars at the sutures, and it is rather completely porulate. It is displaced distally its own width and has no distal overlap. The furrow is indented about 0.3 its width and fades out in the distal quadrant. The pre- and postcingular lists are subequal, each a projecting angle with a heavy suture rib on its margin. The suture lines separating the girdle plates are also heavily ribbed.

The sulcus is narrow, short, extending 0.6 the distance from girdle to postmargin, with heavy ribs in its margins. The postsulcal trough is bounded by the suture ribs which run down the ventral sides of the antapical horns. The sulcus invades this area which is laterally extended to 2.3 times its vertical length.

The plates are everywhere very clearly set off by distinct suture ribs which on the hypotheca laterally and distally have low, hyaline, serrate fins. The seven girdle plates are clearly marked off by ribbed sutures. The anterior intercalary 1^a is a small, almost rectangular plate in the second fifth of the margin of the left shoulder. Postcingular $7'''$ is almost square and widest in the girdle. The surface is completely devoid of any trace of reticulations in all specimens seen. It is rather completely porulate over the whole surface. There are twenty-three pores behind the girdle below the postcingular rim on the dorsal side and two rows in the girdle.

The cell contents in life are very hyaline and include the centrally located ellipsoidal nucleus and a very large, pale yellowish, spherical chromosphere anterior to which was a small pusule from which a sinuous outlet runs to the apical pore.

Dimensions: — One specimen measured. Length, 145 μ; transdiameter,

103 μ; dorsoventral, 83 μ; obliquely along girdle, 92 μ; length of right antapical, 17 μ; of left, 35 μ.

Variation: — Our own scanty material of this species showed no marked variations. Hensen's crudely drawn and inverted figure shows that the antapicals are more nearly equal, but in other particulars the figure is remarkably similar to ours in structural features.

Comparisons: — *Heterodinium laticinctum* is next to the largest of the series including also *H. pavillardi*, *H. inaequale*, and *H. asymmetricum*, all of which have the semicircular outline of the epitheca and unequal, straight, or incurved antapicals. It differs from them all in the fuller development of the girdle rims, the incurved antapicals, and the degree of development of lists. It differs from *H. whittingae*, the terminal and largest member, in the absence of reticulations, wider postmargin, wider girdle, and quadrangular instead of triangular, anterior intercalary plate.

Synonymy: — Hensen (1911) figured this species from the collections of the "Valdivia" as *Peridinium dentatum*.

The type locality is Station 4724 in the South Equatorial Drift.

Occurrence: — *Heterodinium laticinctum* is recorded (Plate **14**) at five of the 127 stations. There are 0, 0, 0, 1, 4, and 0 stations on the six lines of the Expedition. Of these five stations, one (4697) is in the Easter Island Eddy and four (4724, 4732, 4737, 4739) are in the South Equatorial Drift. No specimens were found in any surface haul. All records are from hauls from 300–0 fathoms and the frequency in all cases is less than 1%.

The temperature range at the five stations at the surface was 75°–82°, and the average was 78.8°, a rather high average.

It was reported by Hensen (1911) as *Peridinium dentatum* from the collections of the "Valdivia" at eleven stations, located in the North (1) and South Equatorial (6) Currents, the Sargasso Sea (3), and North Sea (1), the latter probably carried in with the Gulf Stream water.

This species is rare in tropical waters, avoids the surface, is eupelagic and appears to be stenothermal in the higher temperatures.

Heterodinium asymmetricum sp. nov.

Plate **10**, fig. 1–2; Plate **16**, fig. 31

Diagnosis: — A small, rather clumsily formed, asymmetrical species with stout body; 1.13–1.49 transdiameters long; epitheca broadly and asymmetrically rounded; antapical horns very short, very unequal, the right scarcely developed,

the left 0.3 transdiameter long, separated 0.55 transdiameter; girdle oblique (45°) with undeveloped posteingular rim; surface smooth, or with only a few scattered pores. Length, 85–90 μ. Rare in the Eastern Tropical Pacific in the Easter Island Eddy and the South Equatorial Drift.

Description: — In this small stout species the body in face view is almost square with a curved anterior side formed by the outline of the epitheca. The length, apart from the horns, is 0.98–1.11 transdiameters. The body is much compressed dorsoventrally, that diameter being only 0.5 the transverse. The epitheca is a low, asymmetrical dome, about 0.3 transdiameter in height in ventral view, and about 0.75 in dorsal view, with unevenly rounded lateral outlines, the right shoulder being steeper than the left and less regularly curved. In lateral view the dorsal outline is symmetrically concave, with a little flare at the girdle, and the ventral straight and flat with a little median excavation. The midventral suture is vertical from the girdle to the ventral area and then curves 25°–40° to the right to the apical pore. The ventral area is an oblique squarish area about midway between apex and flagellar pore. In its center is the small reniform ventral pore. The apical pore is not emergent.

The hypotheca is a little larger than the epitheca, subconical (15°), and almost squarish in ventral view. The right side grows convex distally, the left is straight, or slightly concave. In lateral view it is also subconical (15°) basally, but at the posteingular suture slopes abruptly ventrally, parallel to the oblique girdle.

The antapical horns are unequal, conical, sharp pointed, wide-set at the posterior corners, and quite variable in size. The left is 0.20–0.42 transdiameter in length, the right even more variable (0.06–0.12), sometimes quite undeveloped beyond a slight point. The right is a broad cone (90°), and the left narrowly conical (25°), tapering distally. The postmargin is an asymmetrical shallow indentation (0.14–0.20 transdiameter) and the distance between tips is 0.52–0.60 transdiameter. The margin often bears a dentate fin.

The girdle is very oblique, its plane sloping ventroposteriorly 45°, narrow, not displaced distally, and without overlap at the distal end, with a narrow overhanging precingular rim, but no trace of the posteingular one. There is no furrow.

The sulcus is a small, narrow, straight groove extending less than 0.5 the distance from the girdle to the postmargin without lists. The postsulcal depression is broad, shallow, and delimited by suture ridges narrowing out to the tips of the antapicals.

The plates are very faintly marked by delicate lines, or, at the most, very narrow ridges. No intercalary zones have been seen. The dorsal precingulars, owing to the foreshortening of the dorsal face of the epitheca, are very narrow. The anterior intercalary 1^a is almost rectangular, is exposed wholly on the dorsal face, and borders the second fifth of the left shoulder. The dorsal slope is so foreshortened as to bring the dorsal edges of apicals 1′ and 3′ over onto the dorsal face.

In all specimens seen, the thecal markings were confined to relatively few, small, scattered pores. Not a single reticular bar has been seen on any specimen. The only fin is the serrated one extending along the postmargin.

The theca and cytoplasm are very hyaline in life. An ellipsoidal nucleus, 0.2 transdiameter in length, lies in the center of the epitheca viewed ventrally. Immediately behind and below it is a spherical, very pale yellow chromatophore.

Dimensions: — Four specimens measured. Length, 95.5 (85–104) μ; transdiameter, 70.2 (65–75) μ; dorsoventral diameter, 36 (35–37) μ; length of right antapical, 7 (5–9) μ; left, 22 (15–27) μ. Transdiameter measured along the oblique girdle 52 μ.

Variation: — This is most obvious in the relative lengths of the right antapical horn, distance between antapicals, and shape of the postmargin.

Comparisons: — The species described by Pavillard (1916) as *H. Kofoidi*, and here renamed *H. pavillardi* (page 86), is very closely allied to *H. asymmetricum*. In the latter the antapical horns are more widely set and divergent, 0.3 transdiameter between axes in *H. pavillardi* and 0.5 in *H. asymmetricum*. The apical pore is much wider in the former, the left antapical horn is less robust than in the latter, and its antapical region bears heavy serrated fins. In *H. asymmetricum* this fin is limited to the postmargin between the horns. It is also close to *H. inaequale* Kofoid, but differs from it in smaller size, 95.5 (85–104) μ as compared with 116–120 μ, in not having an emergent apical pore, and in the absence of any displacement of the distal end of the girdle. In *H. inaequale* this is displaced a girdle width. The postmargin of the latter has a central bay which is lacking in *H. asymmetricum*.

The type locality is Station 4699 in the Easter Island Eddy.

Occurrence: — *Heterodinium asymmetricum* is recorded (Plate **14**) at only four of the 127 stations of the Expedition, 1 on the third, and 3 on the fourth line of the Expedition. Of these four stations, two (4691, 4699) are in the Easter Island Eddy, and two (4701, 4715) are in the South Equatorial Drift. The frequency was in all cases less than 1%, and all records are from hauls from 300–0

fathoms. The surface temperatures at the four stations ranged from 72° to 75° and averaged 73.8°.

It is eupelagic and rare.

Heterodinium laeve Kofoid and Michener

Plate **11**, fig. 1, 3, 5, 7; Plate **16**, fig. 33

Heterodinium laeve Kofoid & Michener, 1911, p. 284–285.

Diagnosis: — A large, hyaline, asymmetrical species with narrow, oblique girdle; length, 1.7 transdiameters; epitheca less than a semicircle in outline; apical pore deflected dextroventrally; right antapical about 0.5 length of left, both incurved and deflected to the right, tapering to a fine point; postmargin asymmetrically concave; no postcingular rim; no reticulations. Length, 150–170 μ. Rare in the Panamic Area, South Equatorial Drift, and Easter Island Eddy.

Description: — This is a large, decidedly asymmetrical species with an oblique girdle, long hypotheca pushed to the right, and antapicals deflected to the left. The epitheca is about 0.5 of the hypotheca. In dorsal view its height is 0.33 transdiameter, a low dome, asymmetrically more convex on the right than on the left side. The apical pore is not emergent, is deflected 25° to the right of the median line, and lies over the apical margin on the ventral surface. In ventral view, the epitheca is scoop-shaped with a wide symmetrical depression extending to the lateral interapical sutures. The midventral suture is angled (130°) at the ventral area which is located a little below the middle as a small quadrangular area with a minute, broadly reniform, centrally located ventral pore. In lateral view the epitheca has a subconical (55°) outline with rounded apex and nearly straight sides.

The hypotheca is quadrangular in all views with nearly straight sides above the postcingular-antapical suture. Its departures from this shape are due to its dextral deflection. In dorsal view its right margin is convex and bulging and its left is straight and sloping 20° to the right. In lateral view its dorsal face is straight, flaring abruptly dorsally at its antapical suture. Its ventral contour is gently concave with a rather deep median depression. Below the antapical suture it is squarely inset for 0.3 transdiameter on the right, and 0.2 on the left, the antapical horns arising in line with its ventral face.

The antapical horns are unequal and sharp pointed, the right being about 0.5 the length of the left. The right has a straight outer margin and a concave

inner one, is subconical (30° basally, 15° distally), and deflected 25° to the left. The left is more tapering, subconical (20° basally, 10° distally), its outer margin straight basally, convex distally, and the inner concave throughout. It is deflected 30°–40° to the left, but distally the tip is incurved to, or beyond, the vertical. They are wide-set, the distance between the middle of their bases being 0.6 transdiameter and between their tips 0.85 transdiameter. The postmargin is very asymmetrically concave, deepest towards the right, and often straight and horizontal for nearly 0.5 transdiameter near its middle.

The girdle is very oblique, inclined ventrally nearly 45° from the horizontal, displaced distally only 0.5 girdle width, and its ends scarcely meet. It is quite narrow, its width being only 0.1 transdiameter.

The precingular rim is feebly developed as a projecting angle. There is no postcingular rim at all, except a vague line in the proximal quadrant. The furrow is entirely lacking.

The sulcus is narrow, straight, runs for 0.75 the distance between the girdle and the postmargin, slightly invades the postsulcal trough, and expands slightly just below the flagellar pore which lies at the junction of sulcus and girdle. There are no lists along its margins.

The plates are defined clearly by suture lines and, in some cases, by border lines of pores. Distinct suture ribs have been seen on the interpostcingular sutures in one specimen. The plates are sparsely porulate. Only one line of pores occurs in the girdle. No lists of any kind were seen on the theca.

The whole organism is remarkably hyaline and transparent. The cell contents are unknown.

Dimensions: — Four specimens measured. Length, 143 (125–155) μ; transdiameter, 90 (75–100) μ; dorsoventral diameter, 62 μ, obliquely along girdle, 73 μ; length of right antapical, 28 (25–30) μ; of left, 58 (55–62) μ.

Variation: — Beyond the considerable variation in size our material shows also some variation in the absolute and relative length and degree of deflection and curvature of the antapical horns, and in the flatness of the postmargin. There is also much variation in the distinctness of the sutures and pores.

Comparisons: — *Heterodinium laeve* differs from *H. gesticulatum* in its greater inequality of the antapicals, less inequality of the two sides of the hypotheca, and the weaker precingular rim of the girdle.

The type locality is Station 4739 in the South Equatorial Drift.

Occurrence: — *Heterodinium laeve* is recorded (Plate **14**) at nine of the 127 stations. There are 0, 1, 2, 4, 2, and 0 stations on the six lines of the Expedition.

Of these nine stations, one (4637) is in the Panamic Area, five (4689, 4691, 4695, 4697, 4699) are in the Easter Island Eddy, and three (4701, 4730, 4739) are in the South Equatorial Drift. Two of the three are clustered in or near the Easter Island Eddy. No specimens were recorded from surface hauls. At the nine stations it was recorded from hauls from 300–0 fathoms and at Station 4701 also from 800–0 fathoms.

The temperature range of these nine stations at the surface was 72°–79° and the average was 75°.

The frequency was 1% at Station 4699, and less than that at all others.

This species is cupelagic and stenothermal in the warmer South Equatorial region of the Eastern Tropical Pacific with a center of occurrence in the Easter Island Eddy. Its absence from the surface and its extreme hyalinity are indicative of its limitation to the deeper levels.

The *gesticulatum* group

Plate **12**, fig. 1–5; Plate **14**; Plate **16**, fig. 34–40; Plate **19**; fig. 59–65; Plates **20**, **21**, **22**, fig. 82–85

This series is characterized by the presence of the sinistral lobe on the hypotheca, a deep concavity on the right margin of the hypotheca, overhanging epitheca, and denticles at the postcingular-antapical suture on the left margin. The series contains six species, namely, *H. mediocre* (Kofoid), *H. sinistrum* sp. nov., *H. deformatum* (Kofoid), *H. gesticulatum* Kofoid, *H. extremum* (Kofoid), *H. varicator* sp. nov., all described from collections of the Expedition; and *H. scotti* sp. nov. from the tropical Atlantic.

Heterodinium mediocre (Kofoid)

Plate **16**, fig. 36; Plate **19**, fig. 59–65; Plate **21**, fig. 74

Heterodinium gesticulatum forma mediocris Kofoid, 1907a, p. 165, 181, pl. 6, fig. 39.

Diagnosis: — A large subsymmetrical species with broadly rounded apex, slight precingular constriction on both sides; length 1.69 transdiameters; epitheca overhanging equally on both sides; hypotheca longer, its sinistral lobe not prominent, usually bidentate; antapicals short, stout; postindentation asymmetrical, nearly a right angle, quite shallow; anterior intercalary quadrangular, precingular 2″ wide, postcingular 7′ ″ pentagonal; surface reticulated. Length, 122–145 μ. Rare in the South Equatorial Drift, Easter Island Eddy, and South Equatorial Current of the Eastern Tropical Pacific.

Description: — The body is stout, robust, subsymmetrical, with subequal epitheca and hypotheca in ventral view. Its length is 1.69 (1.57–1.88) transdiameters. The epitheca in ventral view is 0.80–0.94 and in dorsal 0.44–0.55 transdiameter in length, equalling, or slightly exceeding, that of the hypotheca. In ventral view its outline is irregularly semicircular anteriorly, deflected to the right, and, in consequence, fuller than on the left. Its area is, however, greater than a semicircle, since the height of the epitheca exceeds the radius which only reaches to about the median ventral pore. The epitheca is widest at about the level of the ventral pore, constricting unequally on the two sides, somewhat more on the right than on the left side, and flaring again a little near the girdle. The midventral suture bends to the left at the apical-precingular suture, making an angle of 150°–160°, at the median quadrangular ventral area which has a central reniform ventral pore. The apical pore and lateral interapical suture are carried onto the ventral face by the ventral inclination of the apical region.

The hypotheca is large, its length in ventral view being 0.76–1.00 that of the epitheca. In ventral view it is rather asymmetrical due to the sinistral lobe which projects not over a girdle width at the postcingular-antapical suture which is deflected posteriorly about 45°. The outline of the lobe is broadly rounded without a large protuberant extension. It bears one or two small acute denticulations, one anterior to the suture, generally present, and one on the posterior side of the suture, less regularly present. The right margin is rather evenly and slightly concave.

The antapical horns in ventral view are conical in outline, subequal, quite stout and unequally divergent. The right horn is the smaller, concave on its outer margin, becoming concave distally, nearly straight on the inner, diverges to the right 30°, and is subconical (30°–45°). The left antapical is much stouter and a little longer, concave basally on the outer side, becoming straight distally, and straight throughout the inner face. It is conical (55°–90°) and sharp-pointed, as is also the right antapical. The lengths of the horns are quite variable, the right ranging from 0.14–0.26 and the left from 0.24–0.48 transdiameter. The postindentation is wide and very shallow, asymmetrically deeper to the right, subangular (75°–90°), with a broad, coarsely serrated, marginal fin.

The girdle is slightly oblique. Its distal end is displaced posteriorly about 0.5 girdle width. Its proximal end is narrowed as it approaches the flagellar pore and its distal end is slightly widened. It is rather wide, 0.17 transdiameter in width, and has no overlapping of the ends. The precingular list is formed by the very unusual overhang on all sides of the epitheca over the contracted hy-

potheca. The posteingular ridge is almost wholly lacking throughout, at least as an elevation above the hypotheca, and the furrow is impressed less than 0.3 its width.

The sulcus is very short, 0.50–0.65 the distance from the flagellar pore to the postmargin in length, almost straight, very narrow, and invades the postsulcal trough only a short distance.

The plates are clearly marked by suture ribs. The anterior intercalary plate 1^a is broadly quadrangular and confined to the dorsal surface. Posteingular 7′ ″ is pentagonal and elongated below the level of the posteingular ridge. The surface is reticulated throughout in the same general pattern of the reticulated parts of *H. gesticulatum* (Plate **12**, fig. 1–3), but no intercalary zones, secondary reticulations, or bald plates were observed in *H. mediocre*.

A spherical centrally located nucleus was detected in one specimen. In life one specimen recorded at Station 4689 had a cluster of about a dozen minute, spherical, yellowish-green chromatophores clustered about the central nucleus.

Dimensions: — Six specimens measured. Length, 131 (118–145) μ; transdiameter, 77.5 (70.0–85.0) μ; length of right horn, 28 (10–35) μ; of left, 32 (17–37) μ; diameter of nucleus, 20 μ.

Variation: — This species varies (Figures 59–65) in the depth of constriction of the epitheca; ventral deflection of the apical pore; length, spread, and deflection of the antapicals; number and degree of development of the sinistral denticles; and the length, thickness, and deflection of the antapicals.

Comparisons: — This is the least modified of the *H. gesticulatum* group, with the smallest, least recurved sinistral lobe, least deflection of the antapicals, and shortest antapicals. Its postindentation is widest, attaining 90°, and shallowest, a feature which is most characteristic. The one or two denticles on the sinistral lobe are also characteristic, not having been seen on *H. gesticulatum*, *H. extremum*, *H. deformatum*, or *H. varicator*. *H. mediocre* resembles *H. fides* in having a constriction of the epitheca, but very much less of it. The sinistral expansion of the hypotheca is very slight in *H. fides* and it is very much more symmetrical.

Synonymy: — Described as *Heterodinium gesticulatum forma mediocris* by Kofoid (1907a).

The type is from Station 4742 in the South Equatorial Current.

Occurrence: — *Heterodinium mediocre* is recorded (Plate **14**) at seven of the 127 stations. There are 0, 1, 1, 3, 1, and 1 stations on the six lines of the Expedition. Of these seven stations, one (4637) is in the Panamic Area, two (4689, 4699) are in the Easter Island Eddy, one (4715) is in the Galapagos Eddy, three

(4689, 4706, 4724) are in the South Equatorial Drift, and one (4742) is in the South Equatorial Current. All were taken in hauls from 300–0 fathoms at all seven stations and also at one station (4701) from 800–0 fathoms.

The temperature range of these seven stations at the surface was 72°–79° and the average was 75.1°.

The frequency was in all cases less than 1%, except at Station 4715 where it was 1%.

This species is cupelagic, eubathmic, and stenothermal at the higher temperatures and seemingly limited to the warmest tropical currents of the Eastern Tropical Pacific.

Heterodinium sinistrum sp. nov.

Plate 16, fig. 34; Plate 21, fig. 78

Diagnosis: — A large, elongated species with elongated, dextrally deflected and constricted epitheca; length 1.92 transdiameters; hypotheca shorter than epitheca on the right, with left margin vertical to the level of the posterior denticle of the flattened sinistral lobe; no right antapical, the left, vertical, broadly subconical; postmargin nearly a right angle; suture between 1′ and 1″ deflected sinistroposteriorly. Length, 142 μ. Rare in the Panamic Area of Eastern Tropical Pacific.

Description: — A unique and highly aberrant species with dextral deflection of the elongated epitheca, deficient right antapical, and vertically elongated left antapical, all of which features tend to give an unusual elongation and a peculiar asymmetry to the body. The epitheca in ventral view is 0.5 the total length, but more than twice that of the hypotheca to the middle of the postmargin. Its length is 1.1 transdiameters. The anterior outline is broadly rounded, fuller anteriorly at the right than at the left and flattened at the left, due to the deflection of the epitheca anteriorly to the right. The right margin is slightly flattened and concave about midway, and the left is evenly convex to the level of the apical-precingular suture, where, as on the corresponding suture on the right side, there is a slight depression. The concavity is smaller than on the right, and only a girdle width above the precingular rim. This inequality results from the obliquity of the ventral transverse suture between the apical and precingular plates. This suture is inclined sinistroposteriorly about 17°. The interapical lateral sutures above this transverse suture appear to be finned and sparsely ribbed. The midventral suture is deeply angled, 150°, with both arms oblique

to the vertical. The ventral area lies at the left of the median line, is quadrangular, squarish, located midway between girdle and apex, and contains an anteriorly located, minute, reniform ventral pore with the concavity to the right. The apical pore is deflected 5° to the right from the vertical. The epitheca overhangs the hypotheca a little more than 1.5 girdle widths on the right, but is without overhang on the left.

The hypotheca in ventral view is equal to the epitheca on the left half, but greatly reduced on the right. Its right margin is concave and the left is straight and vertical to the level of the postcingular-antapical suture, below which there is a posterior, backwardly deflected, rather long denticle. The right antapical is reduced to a stout, scarcely projecting (0.5 girdle width), bluntly rounded lobe, 0.25 transdiameter wide at its base, and deflected laterally 40° from the vertical. The left antapical is quite normal, except for its vertical position and its displacement towards the median line. Its axis is almost in line with the ventral pore and it is deeply and abruptly concave below the denticle. On its outer face it is a stout, sharp-pointed cone (40° distally and 25° proximally), with a very slightly concave inner border. The postmargin is inverted L-shaped, almost right angled, with the angle rounded, and is inclined to the right. Its left subvertical margin is bordered by a wide irregularly toothed fin.

The girdle is inclined about 20° ventroposteriorly, is not displaced distally, and has no distal overlap. Both the pre- and postcingular ridges are developed subequally in the proximal quadrant, but the epitheca, without any marked precingular flare, overlaps widely on the right margin. The girdle abruptly widens distally, as it reaches postcingular plate 7″ ′, to twice its width elsewhere. The furrow is only slightly impressed.

The sulcus, from the precingular ridge to its end, is 0.66 the distance to the postmargin. It is deflected to the right 10° and, below the large flagellar pore, is uniformly narrow and sinuous.

The plates are clearly marked by sutures. Postcingular 7″ ′ is very wide, nearly two girdle widths, and pentangular. The dorsal view is not known, but from the location of the apical-precingular suture on the right margin, it is evident that precingular 2″ must be a very narrow plate.

The surface marking and cell contents are unknown.

Dimensions: — Length, 142 μ; transdiameter, 77 μ; length of left antapical, 45 μ.

Comparisons: — *Heterodinium sinistrum* is quite unlike all other species of the genus in the suppression of the right antapical horn, and, in compensation, in

the shifting of the right antapical towards the median line, the increase in volume of that part of the epitheca, and the deflection of the epitheca to the right with resulting asymmetry. It is clearly near the *gesticulatum* group and perhaps near *H. fides*. It is the counterpart of *H. deformatum*, in which the left antapical is suppressed, but differs from it in proportions, notably greater elongation, and marked asymmetry of the epitheca; in absence of displacement of the distal end of the girdle; and in the shape of postcingular plate 7″ ′. With the median shift of the left antapical, the sinistral lobe is flattened out so that the left margin is vertical and the denticle is directed posteriorly. The obliquely posterior deflection of the ventral apical-precingular suture is not equalled in any other species.

The type locality is Station 4638 in the Panamic Area.

Occurrence: — *Heterodinium sinistrum* is recorded (Plate **14**) at only one of the 127 stations on the second line of the Expedition at Station 4638 in a haul from 300–0 fathoms in the Panamic Area off the Galapagos Islands.

The temperature at this station at the surface was 75°.

The frequency was less than 1%.

This species is eupelagic, eubathmic, and rare.

Heterodinium deformatum (Kofoid)

Plate **16**, fig. 35; Plate **21**, fig. 73, 75, 76

Heterodinium gesticulatum forma deformata Kofoid, 1907a, p. 165, 181, pl. 6, fig. 40.

Diagnosis: — A medium-sized, stout, asymmetrical species with an expanded epitheca, constricted at the left, with overhang of a girdle's width at the left; length 1.67 transdiameters; hypotheca, excluding horn, less than the epitheca, with very broadly rounded, scarcely developed sinistral lobe without denticle; right antapical, long, tapering; left lacking; postmargin subhorizontal; postindentation right angled; surface as in *gesticulatum*. Length, 127 (123–130) μ. Rare in the South Equatorial Drift of the Eastern Tropical Pacific.

Description: — This is a highly asymmetrical, medium-sized, stout species wholly lacking the left antapical, and with only slight development of the sinistral lobe. In ventral view the length of the epitheca is 1.61 times that of the hypotheca (excluding the right antapical) and its width 1.24 times that of the hypotheca. It has considerably the greater volume. Its length in ventral view is 0.9 transdiameter. In dorsal view the epitheca and hypotheca are subequal. Anteriorly the epitheca is subsemicircular in outline, fuller at the right than at the left, and has a slight constriction above the precingular ledge on the left, but none

on the right. About midway of the epitheca it expands up to 0.59 girdle width more than the precingular transdiameter. The apical pore is deflected about 10° to the right and is shoved over onto the ventral face. The epitheca overhangs the hypotheca 0.5 a girdle width at the right and about 1.0 at the left. The midventral suture is angled 160° to the left and the ventral area lies on it midway between the apex and the girdle. It is unequally quadrilateral, with an anteriorly located, very small, reniform ventral pore, with the concavity facing to the right.

The hypotheca, exclusive of the right antapical, is about 0.5 transdiameter in length, and has a concave right and left margin. Its sinistral lobe is scarcely developed and is merged with the rounded and undeveloped left antapical region. There is no denticle at the postcingular-antapical suture or, at the most, only a faint indication of one. The right antapical horn is vertical, or deflected 25° to the right, conical (25°), and sharp-pointed. There is no left antapical horn. The postmargin is right angled, L-shaped with rounded corner, and with or without a narrow, sparsely toothed fin. The depth of the postindentation is about a girdle width.

The girdle is submedian, displaced distally about 0.5 a girdle width, and is without distal overlap. It fades out distally. The precingular ridge is fairly well developed as a slightly everted edge of the overhanging epitheca. The postcingular rim is deficient, being a slight elevation in the proximal quadrant only. The furrow is indented only in the proximal part, the curve below the precingular ridge being more pronounced in that region. The width of the girdle is 0.12–0.14 transdiameter and it flares in the distal quadrant.

The sulcus is very short, less than 0.5 the distance from the postcingular rim to the postmargin in length, oblique, deflected 30° to the right, and has an overhanging tooth at the middle of the right margin.

The plates are clearly defined by distinct sutures. The anterior intercalary 1^a has a horizontal width of 1.5–2.5 its vertical height and fills about the second fifth of the left margin of the epitheca. It lies wholly on the dorsal face. Precingular 2″ is about equal to it in shape and lateral extent. Postcingular 7′″ is obliquely quadrilateral and twice as long as wide. The postcingular-antapical suture on the dorsal face is inclined sinistroposteriorly 20°–25°.

The surface marking and cell contents are unknown.

Dimensions: — Two specimens measured: length, 127 (123–130) μ; transdiameter, 82 μ; greatest diameter, 86 (85–87) μ; length of right antapical horn, 41.5 (38–45) μ.

Variation: — Our two specimens differ in the obliquity of the right antapical horn, the angle of the postmargin, and the width of the girdle.

Comparisons: — *Heterodinium deformatum* is unique in the genus in the suppression of the left antapical. The shape of the epitheca and the slightly developed sinistral lobe, broadly rounded and fused with the antapical region, is indicative of its affiliation with the *gesticulatum* section of the subgenus Platydinium. It does not have the habitus of a mere abnormality, especially in view of the diversification of this section as a whole. Furthermore, its characters, aside from the left antapical, are not those of any species of the genus. It is nearest to *H. varicator*, but has a different right antapical, anterior intercalary, and sinistral lobe.

Synonymy: — The species was described as *H. gesticulatum forma deformata* by Kofoid (1907a).

The type locality is Station 4724 in the South Equatorial Drift.

Occurrence: — *Heterodinium deformatum* is recorded (Plate **14**) at only two (4724, 4736) of the 127 stations, both on the fifth line of the Expedition from hauls from 300–0 fathoms in the South Equatorial Drift.

The frequency was less than 1%.

The temperature range at the two stations at the surface was 79°–81° and the average was 80°, a high level.

The species is eupelagic, narrowly stenothermal, and eubathmic in the center of the East Tropical Pacific.

Heterodinium gesticulatum Kofoid

Plate **12**, fig. 1–5; Plate **16**, fig. 37; Plate **22**, fig. 86

Heterodinium gesticulatum Kofoid, 1907a, p. 165, 180–181, *partim.*
H. gesticulatum forma typica Kofoid, 1907a, p. 165, 181, pl. 6, fig. 37; Hensen, 1911, p. 174.
Peridinium tristylum Hensen, 1911, p. 174, fig. C, 10, Tab. XVII, *non P. tristylum* Stein, 1883, p. [48], pl. 9, fig. 15–17.

Diagnosis: — A large asymmetrical species with semicircular apical outline, constricted at left above girdle, overhanging the girdle a girdle width at the right; length 2.25 transdiameters; hypotheca short with large lateral lobe on left margin above postcingular-antapical suture; right antapical uniformly conical (25°), without a distal bay on inner face; postindentation subangular, subtending 45°; anterior intercalary rather narrow, precingular 2″ and postcingular 7′″ narrow; surface heavily reticulated except on left anterior region. Length, 130–145 μ. Widely distributed in Eastern Tropical Pacific from the Mexican Current to the Easter Island Eddy.

Description: — The asymmetry of this large species is accentuated by three major structural features, (1) the overhang of the epitheca at the right precingular region, (2) the massive sinistral lobe below the girdle, and (3) the dextral deflection of both antapicals. This results in a bizarre form of body which in ventral view presents a normal dome-shaped epitheca but a much distorted hypotheca. The length is 1.86–2.00 transdiameters and the dorsoventral diameter about 0.75 the transverse measured on the precingular ridge.

The epitheca in ventral view is asymmetrically dome-shaped with a length of 0.95–1.11 transdiameters at the precingular ridge. Its outline anteriorly is almost semicircular, a little fuller at the left. The right margin becomes almost straight as it approaches the girdle, but on the left there is a slight constriction above the girdle. In one specimen the expansion above the constriction slightly exceeded the diameter at the girdle. In lateral view the epitheca is subconical (60°) with the ventral side steeper and flatter than the more rotund dorsal side. The midventral suture is almost straight, is inclined to the right anteriorly, and has a median quadrangular ventral area with a minute bilobed ventral pore centrally located.

The hypotheca is strangely distorted, so much so as to make description in the usual terms difficult. The massive left lobe has seemingly appropriated some of the substance of the hypotheca and in consequence it appears that the right side has collapsed inward, the main part has been foreshortened, and the antapicals have been pulled basally towards the lobe with a resulting obliquity. In ventral view the hypotheca is 0.85–0.90 transdiameter in length and only 0.81–0.84 transdiameter in width at the girdle, due to the overhang of the epitheca. On the dorsal side it is a little less than one transdiameter in length. In ventral view the right margin is quite concave but the left is expanded in a massive lobe above the postcingular-antapical suture which is convex outwardly and turns abruptly horizontally at a right angle at the suture. The angled tip of the lobe is scarcely recurved posteriorly. In lateral view the dorsal surface is basally broadly convex, curving ventrally below the postcingular-antapical suture to the antapicals which arise well towards the ventral face. Ventrally the hypotheca is deeply excavated in the midventral region.

The antapicals are conical, pointed, unequal, spreading, and much deflected to the right. The right is the longer, but more slender conical (20°), 0.57 transdiameter in length, and deflected 25° to the right. The left is much stouter, conical (35°), blunter, 0.33 transdiameter in length, and is also deflected to the right 10°. The postindentation is asymmetrical, deeper at the left, subangular

(25°), with narrowly concave serrated postmargin scarcely more than a girdle width wide. The distance between tips is about 0.5 transdiameter.

The girdle is submedian and in its proximal and distal quadrants curves posteriorly. Dorsally it is almost horizontal. It is without distal overlap and its distal end is displaced posteriorly less than 0.5 a girdle width. The precingular ridge is well developed throughout as a thick, angled, but very low shelf. The postcingular ridge is almost wholly lacking. The furrow is only feebly impressed and fades out posteriorly.

The sulcus is very short, almost comma-shaped, and does not extend below the postcingular-antapical suture. It is without lists but is bordered by a heavy rib.

The plates are marked by heavy suture ribs, and in the specimen figured on Plate **12**, fig. 1–5, the sutures between many of the plates have widened out in intercalary bands. The lateral interapical sutures are carried over on the ventral face. The anterior intercalary 1^a is a very wide plate, broadly quadrangular, at the expense of precingular 2″. Postcingulars 1′″ and 7′″ are both small as a result of the foreshortening of the basal part of the hypotheca. Plate 7′″ is rectangular and scarcely longer than the girdle width.

The surface is coarsely and heavily reticulated, except on plates 1′, 2′, 5″, and the dorsal side of the two antapicals. Invading (or retreating ?) reticulations are present on 1′ and 2′ adjacent to or bordering fully reticulated plates (Plate **12**, figs. 1, 4). These are only faintly outlined on plate 1′. There are fifteen polygons along the midventral suture, eighteen in the reticulated part on the dorsal side, and twenty-eight on the ventral side anterior to the girdle. The polygons, and also the area without reticulations, are porulate. The girdle has an interrupted series of 2–3 plates. Secondary reticulations appear in the intercalary zones. A specimen without intercalary zones was reticulated throughout. The curious irregularity in the distribution of reticulations seems not to be correlated with fission or any possible fission-line. It occurs in connection with the appearance of intercalary zones and might be a phase of resorption or of other regulatory processes in conjunction with approaching ecdysis.

The cell contents in a preserved specimen include a very large (25 μ), spherical, centrally located nucleus, a chromosphere adjacent to it, and a cluster of refractive (amyloid?) bodies gathered about the nucleus.

Dimensions: — Two specimens measured. Length, 142–170 μ; transdiameter at precingular ridge, 70–100 μ; dorsoventral, 85 μ (one specimen); length of right antapical, 42 μ; of left, 39–42 μ; diameter of nucleus, 25 μ.

Variation: — In the limited material of this species as here delimited, there is some variation in size, in the relative lengths of the antapicals, in the depth of the precingular constriction of the epitheca, in the extent of reticulation, and in the presence of intercalary bands and secondary reticulations. The last-named features are probably concerned with approaching ecdysis.

Comparisons: — *Heterodinium gesticulatum* belongs in the series with *H. mediocre, H. extremum, H. deformatum,* and *H. varicator.* Its sinistral lobe is more massive than in any of these species, and less recurved and less pointed than in *H. extremum.* Its antapicals are less deflected and longer than in *H. varicator,* and the postindentation is narrower, more angular, and deeper than in *H. varicator* and (except for depth) *H. extremum.* It lacks the abrupt diminution on the inner face of the right antapical of *H. extremum* and the left antapical is not deformed or deficient as in *H. deformatum.*

Synonymy: — This species was described by Kofoid (1907a) with four divisions, each designated as a *forma.* As here delimited *H. gesticulatum* is restricted to *forma typica* Kofoid (1907a). The other divisions *forma deformata, forma mediocris,* and *forma extrema* are raised to specific rank, as each has a consistent group of differential characters mainly centering in the antapicals, postindentation, and sinistral lobe. A fourth species, *H. varicator,* is also segregated out of the complex on the same grounds.

The type locality is Station 4594 in the Mexican Current.

Occurrence: — *Heterodinium gesticulatum* is recorded (Plate **14**) at sixteen of the 127 stations. There are 1, 1, 6, 5, 3 and 0 record stations on the six lines of the Expedition. Of these sixteen stations, one (4594) is in the Mexican Current, one (4634) is in the Panamic Area, ten (4679, 4681, 4683, 4687, 4689, 4701, 4705, 4724, 4732, 4737) are in the South Equatorial Drift, and four (4691, 4695, 4697, 4699) are in the Easter Island Eddy. No specimens were taken in surface hauls. It was taken in hauls from 300–0 fathoms at the sixteen stations and in addition at Stations 4681 and 4689 also in hauls from 800–0 fathoms.

The temperature range at these sixteen stations at the surface was 68°–84° and the average was 74.8°.

The frequency was 1% at Stations 4689 in hauls from both 300–0 and 800–0 fathoms, and at 4697. At all other stations it was less than 1%.

It was reported by Hensen (1911) as *Peridinium tristylum* in the collections of the Plankton Expedition at nineteen stations with a computed total of 270 individuals. These stations were distinctly limited to tropical regions, two being located in the North and seven in the South Equatorial Currents, respectively;

two in the Florida Current; one in the Gulf Stream Drift; three in the Brazilian Current; three in the Canary Current; and one in the Guinea Current.

This species is widely distributed in the Eastern Tropical Pacific and the tropical Atlantic. It is one of the most prevalent, its record of occurrences (16) being exceeded only by those for *H. milneri* (19), *H. rigdenae* (23), and *H. curvatum* (17). It is eupelagic, eurythermal, and eubathmic. Its large size may contribute to the frequency of its records.

Heterodinium extremum (Kofoid)

Plate **16**, fig. 38; Plate **21**, fig. 79–81; Plate **22**, fig. 82, 83, 84

Heterodinium gesticulatum forma extrema Kofoid, 1907a, p. 165, 181, pl. 6, fig. 38.

Diagnosis: — A large quite asymmetrical species with low, broadly rounded epitheca, deeply constricted above the girdle on both sides; epitheca overhanging more on the right than on the left; length, 1.83 transdiameters; hypotheca short, its sinistral lobe long, recurved, pointed, no denticles at the postcingular-antapical suture; antapicals long, subequal, the right with an abrupt constriction on the inner face, distance between tips less than 0.66 transdiameter; postindentation subangular (45°), asymmetrical, more than 0.5 transdiameter in depth; anterior intercalary very wide, surface often incompletely reticulated. Length, 120–140 μ. Rare in the South Equatorial Drift and Easter Island Eddy of the Eastern Tropical Pacific.

Description: — This is a large, very asymmetrical, quite elongated species. Its length is 1.80 (1.71–2.00) transdiameters. In ventral view the epitheca and hypotheca are subequal in length, but the epitheca has the larger mass. The asymmetry affects the epitheca in the deflection of the apical pore to the right 15°, in wider overhang of the epitheca on the right side, and in the higher level of precingular constriction on the right than on the left side. The epitheca in ventral view is almost semicircular in its anterior part, tilted to the right, and constricted anterior to the girdle to a little less than the transdiameter. The constriction is about two girdle widths above the precingular ridge on the right and immediately above it on the left. The epitheca in ventral view has a length of about 0.8 transdiameter, and its greatest width (1.09–1.18 transdiameters) is found obliquely about midway of its length. In dorsal view its length is about 0.66 the ventral length. The most outstanding feature is the wide and abrupt overhang of the epitheca beyond the hypotheca. This is at least a girdle width at the left margin and may be as much as two girdle widths at the right. The

midventral suture is somewhat angled (140°–160°) and is slightly below the middle of the epitheca. The ventral area is a very small quadrangular region with a minute, stout, reniform ventral pore.

The hypotheca is narrower and, in ventral view, a little shorter than the epitheca. In dorsal view its length is 0.56 that of the epitheca and approximates the transdiameter at the precingular ridge. The hypotheca is widest at the level of the sinistral lobe. The width of the postcingular margin is only 0.66–0.90 that of the precingular ridge, due to the wide and variable overhang of the epitheca. The width at the sinistral lobe is over 0.9 transdiameter. The hypotheca is very asymmetrical, due to the lateral extension of the sinistral lobe and the compensatory concavity of the dextral border. The sinistral lobe lies above the postcingular-antapical suture. It is an angular projection, recurved posteriorly, with very pointed tip from one to two girdle widths long.

The antapical horns are long, somewhat divergent, sharp pointed, and are both deflected strongly to the right. The right horn is 0.67 (0.61–0.74) transdiameter in length, 1.1 longer than the left. It is uniform in width in the proximal 0.66 of its length, 1.0–1.5 girdle widths in diameter, and contracts abruptly on the inner face only, with a concave curve, to a slender tapering point about a girdle width in length. It is deflected 25°–30° from the vertical to the right. The left antapical is symmetrical, conical (25°–35°), pointed, and is deflected to the right into a vertical position, or even slightly beyond it. Its length is 0.59 (0.55–0.64) transdiameter and the distance between tips is about 0.8 transdiameter. The postindentation is asymmetrical, deepest at the right, subangular (50°–60°), and has an asymmetrically concave, rather short postmargin.

The plane of the girdle is oblique, sloping posteroventrally 15°. It is displaced distally half its width and is without distal overlap. The precingular ridge is formed by the projecting epitheca which flares but little. There is no postcingular projection. The furrow is represented by the incurved surface below the overhanging epitheca.

The sulcus is narrow, short, and sinuous, reaching only a bit beyond the postcingular-antapical suture. It is only two girdle widths in length.

The plates are sometimes only very faintly outlined. In another lorica (Figure 79) narrow intercalary bands were developed on the epitheca and wide ones on the hypotheca, with the result that there was less overhang of the epitheca in this lorica than in others. The anterior intercalary 1^a is quadrangular, verging on squarish, and fills nearly 0.33 of the left anterior arc of the epitheca. Postcingular $7''$ is pentagonal, narrowing with a concave right facet within the

girdle. The surface is very unlike, in different loricae, in degree and extent of reticulations. These are of the pattern in *H. gesticulatum*, but in some loricae are very lightly developed. In one instance all the plates except the three entirely smooth apicals were faintly reticulated. In another lorica in ventral view the only reticulated plates were two precingulars (1″, 6″), the girdle plates, and two postcingulars (1‴, 2‴). All other plates on this face were without reticulations, though porulate. In still another theca (Figure 83) on the dorsal face only, were the precingulars (2″, 3″, 4″, 5″) and postcingulars (3‴, 4‴, 5‴) reticulated. In general the reticulations are lighter when present and less uniformly developed over the theca than in other species of the *gesticulatum* group.

The cell contents are unknown.

Dimensions: — Six specimens measured. Length 130 (122–140), μ, transdiameter 72.5 (67–76), μ; length of right antapical 48.2 (42–55), μ; of left 44 (40–48), μ.

Variation: — *Heterodinium extremum* is quite variable in the depth of the precingular constriction of the epitheca; in the overhang of the epitheca; in the lateral extension and amount of posterior curvature of the sinistral lobe; in the deflection of the apical pore upon the ventral surface; in the spread, obliquity, length, and width of the antapicals; and in the number and location of the plates which are reticulated and the degree of reticulation. The development of the intercalary zones modifies the proportions.

Comparisons: — As its specific name indicates this species exhibits extreme conditions of asymmetry, having a longer, more recurved sinistral lobe than in *H. gesticulatum*, *H. mediocre*, *H. deformatum*, or *H. varicator*. The hypotheca is shorter than in *H. mediocre* and the antapicals attain the maximum length in the group. The postindentation is quite like that of *H. gesticulatum*, but deeper, and its outline is modified by the asymmetrical narrowing in the distal part of the right antapical, a character peculiar to this species only, and useful in distinguishing it from the closely related *H. gesticulatum*. The nearer approach to equality of the antapicals in *H. extremum* also distinguishes it from *H. gesticulatum*.

Synonymy: — Described as *forma extrema* of *H. gesticulatum* by Kofoid (1907a), but raised to specific status here because of clearly marked characters consistently present.

The type locality is Station 4699 in the Easter Island Eddy.

Occurrence: — *Heterodinium extremum* is recorded (Plate **14**) at six of the 127 stations with a total of eight specimens. There are 0, 0, 2, 3, 1, and 0 sta-

tions on the six lines, respectively, of the Expedition. Of these six stations, four (4687, 4701, 4707, 4737) are in the South Equatorial Drift and two (4691, 4699) in the Easter Island Eddy. All records are from hauls from 300–0 fathoms.

The temperature range at these six stations at the surface was 72°–75° and the average was 74.4°.

The frequency at Station 4699 was 3% and less than 1% at all others.

Heterodinium varicator sp. nov.

Plate 16, fig. 39; Plate 20, fig. 66–72

Diagnosis: — A large, stout, quite asymmetrical species with very little constriction of the anteriorly rounded, posteriorly squarish epitheca, and slight overhang beyond the hypotheca; length, 1.50–2.15 transdiameters; hypotheca longer, with less protuberant, often broadly rounded sinistral lobe, with or without a denticle; antapicals long, much deflected to the right, generally subequal, distance between tips more than 0.66 transdiameter; postindentation broadly concave, asymmetrical; surface reticulations variable in degree and extent. Length, 125–155 μ. Rare in the South Equatorial Drift and Easter Island Eddy of the Eastern Tropical Pacific.

Description: — This stout species has a high degree of asymmetry mainly in the hypotheca, caused by the larger mass in the sinistral lobe and by the extreme dextral deflection of the antapicals. The epitheca, on the other hand, is less modified and more symmetrical than the hypotheca. In ventral view the epitheca and hypotheca are equal in length, but in dorsal view, owing to the obliquity of the plane of the girdle, the epitheca is only 0.50–0.57 of the length of the hypotheca. In one specimen (Figure 66) from Station 4681 the epitheca was more nearly equal to (0.93) the hypotheca. The epitheca is subsemicircular, slightly subangular (Figures 64, 65), or flattened (Figure 67), or even asymmetrical, with the apical region inclined to the left. In its basal half the lateral margins become nearly vertical and there is only a trace of precingular constriction, often a bit more on the left than on the right side. The epitheca overhangs the hypotheca about 0.50 a girdle width on the left and 0.75 on the right. The midventral suture is slightly angled (150°) and the ventral area is large, elongated subtriangular, with centrally located, rounded, reniform ventral pore. The apical pore is deflected ventrally below the margin and a trifle to the right.

The hypotheca is excavated midventrally and its width at the postcingular margin is 0.80–0.85 that of the epitheca at the precingular margin. Its right

margin is deeply concave, deepest below the postcingular-antapical suture, and the left is asymmetrically convex with a massive sinistral lobe, generally broadly rounded, sometimes bluntly pointed, and only in one instance with a denticle above the postcingular antapical suture. The postmargin is an asymmetrical, subsemicircular, broadly concave arc, deepest at the left, its depth varying from 0.38 to 1.67 of the distance between the tips of the antapicals. Its margin is produced by a coarsely and irregularly dentate fin, often better developed at the right.

The antapicals are subequal, both incurved, pointed, and subconical. The right is the smaller, 20°–25°, but somewhat longer, about 0.6 transdiameter in length, and deflected dextrally 30°–53° from the vertical. The left extends farther posteriorly, is shorter, rarely a little more than 0.5 transdiameter in length, stouter, 30°–50°, and has less dextral deflection (10°–30°). The distance between the tips is 0.60–0.65 transdiameter.

The plane of the girdle is deflected ventroposteriorly about 20°. Its width is about 0.14 transdiameter, is subject to minor inequalities on the dorsal side, and widens in the distal quadrant. It is without overhang and is displaced distally less than 0.5 girdle width. The precingular margin is an overhanging ledge without lateral projection. There is no postcingular ledge. Its furrow is unequally developed, concave anteriorly, and flattening out posteriorly and distally.

The sulcus is short, its length being about 0.75 the distance from the precingular ledge to the postmargin. It is oblique, of equal width throughout, slightly sinuous, and devoid of lists.

The plates are distinctly outlined by narrow suture lines. The anterior intercalary lies wholly on the dorsal side, is quadrangular, and considerably larger than the adjacent precingular 2″. Its lateral margin almost fills the second quarter of the left margin of the epitheca. Postcingular 7″′ is short and wide. The suture between the postcingulars and antapicals on the dorsal side is very oblique. Wide intercalary zones with fine secondary reticulations were found between the postcingulars in one very large specimen. The surface is very unevenly and often irregularly reticulated. In some individuals the reticulations on the entire surface are very faint. In the large specimen above referred to, the pre- and postcingulars were finely reticulated and the apicals and antapicals coarsely reticulated.

The cell contents are unknown.

Dimensions: — Seven specimens measured. Length, 139 (125–155) μ;

transdiameter, 78.4 (68–90) μ; length of right antapical, 45.7 (35–48) μ; of left, 35.7 (25–45) μ.

Variation: — *Heterodinium varicator* shows the greatest variation in the hypotheca, especially in the breadth and mass of the sinistral lobe and in the degree of emergence of a point and a denticle on its end. The obliquity of the antapicals and the accompanying modification in the outline of the postindentation is also quite variable. One specimen (Plate **20**, fig. 68) is so divergent that it is tentatively included here as *forma distortum* **f. nov.** It is characterized by marked inequality of the much deflected antapicals, wide, shallow postindentation, very broadly rounded sinistral lobe, and an asymmetrical epitheca with the apex deflected to the left and the girdle sloping posterodextrally.

Comparisons: — This is the most divergent member of the subgenus Platydinium. It is the most asymmetrical and has the most deflection of the antapicals, but has a less protuberant sinistral lobe. Its postindentation is widest and most nearly semicircular. Its antapicals are longer and more oblique than in *H. mediocre* and *H. deformatum* and have a wider postindentation than in *H. extremum*.

The type locality is Station 4699 in the Easter Island Eddy.

Occurrence: — *Heterodinium varicator* is recorded (Plate **14**) at five of the 127 stations with a total of seven specimens. There are 0, 0, 2, 2, 1, and 0 stations on the six lines of the Expedition. Of these five stations, two (4691, 4699) are in the Easter Island Eddy, and three (4681, 4705, 4734) are in the South Equatorial Drift. No specimens were taken in surface hauls. It was taken in a haul from 800–0 fathoms at Station 4681, and at the other four stations in hauls from 300–0 fathoms.

The temperature range at the five stations at the surface was 68°–81° and the average was 73.8°.

The frequency was less than 1% at all stations.

The species is eupelagic, eurythermal, and is restricted to the deeper levels.

Heterodinium scotti sp. nov.

Plate **16**, fig. 40; Plate **22**, fig. 85

"Peridinean," Wilson E. A., in Scott, R. F. "The Voyage of the 'Discovery,'" 1905, vol. 2, plate facing p. 192. See our Plate **22**, fig. 85.

Diagnosis: — A much elongated and apparently very large species, with an extreme amount of asymmetry; length 2.4 transdiameters; girdle displaced 1.3 girdle widths; epitheca with precingular constriction more anterior on the left

side; length of the hypotheca 1.68 that of the epitheca; sinistral lobe elongated, recurved, pointed; no denticles at postcingular-antapical suture; antapicals subequal, a transdiameter in length, very slender, tapering; postmargin rounded, oblique; postindentation almost the girdle width in depth. Length, 140–160 μ (?). Probably from the tropical Atlantic.

Description: — Body greatly elongated, the length being 2.4 transdiameters. The epitheca is disproportionately small, being only 0.6 that of the hypotheca. Its length is 0.96 transdiameter. The apical region is slightly asymmetrically rounded, somewhat flattened, but almost semicircular in outline. There are unusually deep, precingular lateral constrictions, as deep and wide as the girdle itself on the left, and a less abrupt but exceptionally deep one on the right, a girdle width posterior to the one on the left. The midventral suture appears to be very oblique, deflected about 33° to the right. The suture lines, as drawn by Wilson, leave room for a large ventral area, supplied by conjecture in dotted lines in Plate 22, fig. 85.

The hypotheca is much foreshortened in the section of the midbody and is withdrawn on the right side somewhat more than a girdle width, with resulting wide overhang of the epitheca. Its left side is developed in a very large, protuberant sinistral lobe, with a sharp-pointed, strongly recurved, posteriorly directed projection. There are no denticles whatever at the postcingular-antapical suture.

The antapicals are remarkably symmetrical, incurved distally, very slender, and taper to a sharp point. Their length is about one transdiameter and both are deflected to the right about 20°–30°. The distance between their tips is 0.8 transdiameter. The postmargin is asymmetrically rounded and deepest at the middle.

The girdle is exceptionally well developed, as figured by Wilson, having both pre- and postcingular ridges sharply projecting in horizontal ledges. There is some reduction in the distal quadrant of the postcingular. The girdle has a distal displacement of 1.3 girdle widths. This is more than in any other species in the genus.

The sulcus is evidently very short, scarcely equaling the displaced distal end of the girdle.

The plates appear to be normal. In the reproduction in Plate 22, fig. 85 an interpretation of the suture lines is made which brings Wilson's figure in harmony with the plates in other species. It appears that he must have drawn not only the ventral, but also some of the dorsal, sutures, as though they were on the ven-

tral face of the epitheca. The probable location of the ventral area is blocked out in fine dots in our reconstructed figure and the lines interpreted as dorsal sutures are drawn in dashes. The probable locations of the sulcus and postcingular 7′″ are also dotted in our reconstruction. His original figure is reproduced without the modifications in our Figure 85. The features brought out by this interpretation are the extreme obliquity of the midventral suture, the very large size of the anterior intercalary 1^a shown by its dextromedian border, the very small posteingular 7′″, and the unusual anterior extension of antapical 1′″.

Dimensions: — Since no magnifications are given for Wilson's figure, its size can only be conjectured. If it is of the same order of magnitude at the girdle as other species of the *gesticulatum* group, its length is about 140–160 μ.

Comparisons: — *Heterodinium scotti* differs from all other members of the *gesticulatum* group in the relatively small epitheca; the extreme displacement of the girdle; the inequality of level of the lateral constrictions of the epitheca on the left and on the right side; the considerable obliquity of the midventral suture; and especially in the size, elongation and curvature of the sinistral lobe and the compensatory deflection of the apical region to the right. The elongation and tapering form of the antapicals is not even approached in any other species of Heterodinium.

Synonymy: — In Captain R. F. Scott's "Voyage of the 'Discovery'" (1905) vol. 2, Mr. E. A. Wilson figures, on the plate facing p. 192, among his "Peridineans caught on the voyage out" along with a Phalacroma and an Ornithocercus, this species, which we here name in honor of the renowned explorer of the Antarctic. This is the first species of the genus Heterodinium to have been figured, though not named by discoverer, Dr. Wilson.

The only type locality that can be assigned to this species, and that questionably, is the tropical Atlantic.

Distribution: — *Heterodinium scotti* is clearly tropical in its habitus, as indicated by its elongated antapicals and sinistral lobe. Confirmation of this appears in its association (?) with Phalacroma and Ornithocercus. The route of the "Discovery" on the way out traversed the tropical Atlantic, but no other tropical regions, so it is quite certain that this species came from the tropical Atlantic.

Dolichodinium gen. nov.

Heterodinium Kofoid & Michener, 1911, *partim*, p. 285, as *H. lineatum;* see also *Heterodinium.*

Diagnosis: — Body sub-biconical, subangular, elongated; without apical or antapical horns; girdle submedian, spirally descending, widening at the distal end; postcingular rim deficient; sulcus not indenting the epitheca; plate formula, 4′, 0ᵃ, 6″, 6 (?), 6″ ′, 0ᵖ, 3″ ″; postcingular 6″ ′ invading the distal end of the girdle; wall porulate; fission line subvertical, passing through the apical pore.

Description: — The plate formula is the outstanding feature of this genus and, in the absence of evidence of generic characters from other species than the single one known, the description will be confined to a discussion of this character. The plates are clearly defined by suture lines and, except in girdle series, have been definitely analyzed. The apicals, 1′–4′, are subequal in length. Plates 1′ and 4′ are on the ventral face and 2′ and 3′ on the dorsal. Plate 3′ is connected with the apical pore only by a somewhat narrowed anterior extension. There is no anterior intercalary 1ᵃ, but it is probable that apical 2′ is derivable from 1ᵃ of Heterodinium or *vice versa.*

This genus is created for a species placed tentatively by Kofoid and Michener (1911) in the genus Heterodinium as an aberrant member. It is now separated because (1) of differences in thecal structure, having in the epitheca four apicals, 1′–4′, and no anterior intercalary 1ᵃ; the corresponding formula in Heterodinium being 3′ and 1ᵃ; because (2) of the shifting of antapical 1″ ″ into position distinctly as a large postsulcal plate; because (3) there are six instead of seven postcingulars; and finally and preëminently because (4) the theca is divided into right and left moieties at binary fission, a phenomenon unknown in Heterodinium, by a fission line quite unique in the Peridinioidea in its reaching the apex. The sculpturing of the theca is also of a type found in no member of the genus Heterodinium, and the general facies of this species, in addition to the individual characters above enumerated of morphological significance, would make it an odd figure in that genus.

Comparisons: — The new genus is, however, closely allied to Heterodinium and shows no such obvious affinities with any other genus. While the plate formula differs in the particulars above noted from that of Heterodinium, the two genera have several outstanding characteristic features in common, namely the lack of a posterior girdle rim, the distal widening of the girdle, the thickening of the lateral epithecal sutures, and the presence of a ventral pore at the angle formed by the midventral suture with the apical-precingular suture on the ventral

face of the epitheca. There is, however, no indication of a differentiated ventral area, such as occurs in Heterodinium, in connection with this pore in Dolichodinium. The connections of apical 2′ with the apical pore and its apical extension are rather slight, as though it might be an intercalary 1ª slipping anteriorly into the apical series.

Synonymy: — The type and only known species is *Dolichodinium lineatum* originally described by Kofoid and Michener (1911) as *Heterodinium lineatum*. The type locality is Station 4701.

Distribution: — Known only from the Easter Island Eddy and the South Equatorial Drift of the Eastern Tropical Pacific.

Reproduction: — The specimen figured (Plate **12**, fig. 6–8 and Plate **22**, fig. 87, 88) is very evidently a recent schizont whose anterosinistral moiety of the theca is from the parental source and the posterodextral but newly formed. This is shown in the heavy, opaque structure with large elongated pores in the older part and the delicate, hyaline structure and small circular pores of the newer. The bars along the suture lines are, in places, especially on the epitheca, much more delicate in the newer wall than in the older, although on the ventral hypotheca (Plate **12**, fig. 8) they are clearly thickened, especially distally.

The fission line has the morphological relations characteristic of this structure, at least in parting the theca into somewhat equal moieties along a line which is at the most but slightly oblique, passing through, or near, the flagellar pore. It differs from that in Ceratium in being less oblique and in reaching the apex alongside the plate (apical 2′) most like the intercalary 1ª of Heterodinium, which in Dolichodinium is classed as an apical because it reaches the apex.

This fission line parts the sinistral plates as follows. On the ventral side in passing posteriorly it parts apicals 1′ and 4′, precingulars 1″ and 6″, postcingulars 1‴, and 7‴, antapicals 1⁗ and 2⁗, and postcingular 7‴ from antapical 1⁗. It also goes through or alongside the flagellar pore and sulcus. On the dorsal side it parts apicals 1′ and 3′, precingulars 2″ and 3″, postcingulars 3″ and 4″, and postcingular 2″ from antapical 1⁗. The pores in older and newer parts of the thecal wall are proportional in number and in distribution, but differ in character. In the newer part they are circular or slightly ellipsoidal, while in the older part they are elongated in the direction of the meridian to as much as threefold their transdiameter, and tend to show squarish ends. There is nothing in pattern to suggest the reticulations which are so characteristic of the genus Heterodinium which Dolichodinium resembles in girdle, sulcus, and heavily barred sutures.

Dolichodinium lineatum (Kofoid and Michener)

Plate **12**, fig. 6–8; Plate **17**, fig. 41; Plate **22**, fig. 87, 88

Heterodinium lineatum Kofoid & Michener, 1911, p. 285.

Diagnosis: — A small species with sub-biconical, elongated, slightly polyhedral body; length, 1.5 transdiameters; without horns or spines; girdle submedian, displaced its width, without postcingular ridge; sulcus narrow near the girdle, widening posteriorly; postcingular 7‴ elongated, equal to 1‴; surface with longitudinal rows of elongated pores. Length, 58 μ. Rare in the Eastern Tropical Pacific in the Easter Island Eddy and the South Equatorial Drift.

Description: — In this small species the body is sub-biconical and rather angular, especially in the hypotheca, elongated to a length of 1.5 transdiameters, and circular at the girdle which divides it equally and horizontally. Horns and spines are not developed. The epitheca is subconical (about 70°), having slightly convex lateral margins, more nearly straight dorsal and ventral faces, and flares a little at the precingular rim. The apex is obliquely truncated. The apical pore is very large, being over 0.5 girdle width across, and asymmetrically extended dextroventrally.

The hypotheca is more angular than the epitheca, subconical (60°), and more sloping on the right than on the left. The antapex is very obliquely flattened at an angle of 45°, sloping from the dorsal side ventrally.

The girdle is median, horizontal, and displaced its proximal width at the distal end. Its anterior rim is a heavy projecting shelf without list, which overhangs the shallow furrow at right angles. Its posterior rim is developed. The girdle widens distally to a width almost three times that of the proximal end. The furrow is impressed a bit immediately under the precingular shelf. There is no overlap.

The sulcus is a deep, very narrow groove extending only 0.4 of the distance from the postcingular level to the antapex. The flagellar pore is a minute opening at the level of the postcingular margin. The postsulcal area, however, is widened out in a manner recalling the same structure in Gonyaulax and is not trough-like as in Heterodinium.

The plate formula is 4′, 0ᵃ, 6″, 6 (?), 6‴, 0ᵖ, 3⁗. The apicals are subequal plates, two ventral and two dorsal, with thickened lateral sutures. Of the six precingulars, 1″ and 6″ are the largest, the others being confined to the dorsal face. Postcingular 1⁗ is a small, quadangular plate. Postcingular 7‴ is pushed up into the distal end of the girdle as in some species of Heterodinium.

It is irregularly hexangular, but rounded posteriorly. The remaining postcingulars are large and more or less equal. The three antapical plates are relatively small. Plate 1″ ″ is the pentangular postsulcal plate. Plate 2″ ″ is on the left side and 3″ ″ is obliquely dorsal. The sutures about plate 3″ ″ are heavy ridges, ribbed on the postmargin, and in places developing spines at junctions of the sutures. The plates are marked by numerous large pores, about five across each postcingular at the girdle, which are remarkable in being elongated in the direction of the meridian to as much as threefold their transdiameter and arranged rather obscurely in longitudinal lines. They tend to have squarish ends. There is nothing in the pattern to suggest the reticulations which are so characteristic of Heterodinium. In the specimen figured on Plate 12 the pores in the newer half are very small and not much elongated. There are seventeen pores across the dorsal face anterior to the girdle and eight between girdle and apex. A single row only occurs in the girdle.

In one individual observed in life at Station 4697 the plasma was very hyaline and there was a single, small, greenish-yellow chromosphere on the right side at the end of the girdle.

Dimensions: — Two specimens measured. Length, 58–75 μ; transdiameter, 40–45 μ; width of girdle, 5–6 μ; length of pores, 4 μ.

The type locality is Station 4701 in the South Equatorial Drift.

Occurrence: — *Dolichodinium lineatum* is recorded (Figure 41) at only two of the 127 stations. Both are on the fourth line of the Expedition. One (4697) is in the Easter Island Eddy and one (4701) is in the South Equatorial Drift. Both are in hauls from 300–0 fathoms.

The temperatures at the surface at the two stations were 72° and 75° and the average was 73.5°.

The frequency at each station was less than 1%. *Dolichodinium lineatum* is eupelagic, and confined to the deeper levels.

III. DISTRIBUTION OF THE HETERODINIDAE AT THE STATIONS OF THE EXPEDITION

The following is the record of the genera and species of the Heterodinidae noted by us as the result of examinations, often repeated, of the plankton catches at the various stations of the Expedition.

With each station number we have given the appropriate data including the temperature at the surface in degrees Fahrenheit. Fuller data will be found in the record of stations in Alexander Agassiz's (1906) report of the Expedition.

The occurrences of species at the stations are recorded according to the catch under "Surface" and "300–0 fathoms to the surface," etc. At nearly all stations collections have been made with both No. 12 and No. 20 silk nets. The records of species in the two collections have been combined in a single list. The differences between the two catches lie mainly in the greater proportional loss of the smaller species in the No. 12 net with the coarser mesh. This, together with the fact that the No. 20 catches were more thoroughly examined than those from the No. 12 nets, has made the lists of species from the former somewhat the longer. Since the No. 20 collection generally contained all of the species found in the No. 12 and in larger numbers, there is no change resulting from this combination of the records, except a few instances of additional species from the No. 12, or of larger numbers of individuals of species common to both collections. It follows from this that the sum of the percentages of all species of dinoflagellates at some stations is slightly in excess of 100. This, however, does not appear in these lists since these present only the Heterodinidae.

No Heterodinidae were taken at 66, or 52% of the 127 stations at which dinoflagellates were collected on the Expedition and not a single species was found in Salpa stomachs.

Distribution by Stations

All records of temperature refer to the surface; P = frequency of less than 1%.

4580

Lat. 24° 55′ N., long. 112° 45′ W. October 10, 1904. Temperature, 76°.
300 fathoms to surface: — *Heterodinium rigdenae*, P; *H. scrippsi*, 1%.

4583

Lat. 22° 45′ N., long. 110° 5′ W. October 11, 1904. Temperature, 83°.
Surface: — *H. calvum*, P; *H. milneri*, P.
300 fathoms to surface: — *H. curvatum*, P; *H. rigdenae*, P; *H. whittingae*, P.

4587

Lat. 24° 42′ N., long. 107° 25′ W. October 12, 1904. Temperature, 82°.
100 fathoms to surface: — *H. globosum*, P.
300 fathoms to surface: — *H. curvatum*, P.

4590

Lat. 18° 50′ N., long. 104° 50′ W. October 13, 1904. Temperature, 82°–83°.
Surface: — *H. curvatum*, P; *H. globosum*, P.
300 fathoms to surface: — *H. doma*, P.

4594

Lat. 17° 20′ N., long. 101° 32′ W. October 14, 1904. Temperature, 84°.
300 fathoms to surface: — *H. curvatum*, P; *H. gesticulatum*, P; *H. murrayi*, P.

4596

Lat. 16° 47′ N., long. 100° 27′ W. October 14, 1904. Temperature, 84°.
Surface: — *H. blackmani*, P.

4604

Lat. 12° 21′ N., long. 92° 13′ W. October 17, 1904. Temperature, 84°.
Surface: — *H. globosum*, P.

4605

Lat. 12° 21′ N., long. 92° 13′ W. October 17, 1905. Temperature, 85°.
300 fathoms to surface: — *H. hindmarchii*, P.

4609

Lat. 11° 05′ N., long. 89° 35′ W. October 18, 1904. Temperature, 81°.
300 fathoms to surface: — *H. hindmarchii*, P.

4613

Lat. 9° 45′ N., long. 86° 20′ W. October 19, 1904. Temperature, 80°.
300 fathoms to surface: — *H. rigdenae*, P.

4634

Lat. 4° 35′ N., long. 83° 32′ W. November 4, 1904. Temperature, 80°.
300 fathoms to surface: — *H. gesticulatum*, P; *H. whittingae*, 2%.

4637

Lat. 1° 31′ N., long. 86° 32′ W. November 5, 1904. Temperature, 76°.
300 fathoms to surface: — *H. expansum*, P; *H. laeve*, P; *H. mediocre*, P; *H. rigdenae*, P; *H. scrippsi*, P.

4638

Lat. 0° 27′ N., long. 87° 13′ W. November 6, 1904. Temperature, 75°.
300 fathoms to surface: — *H. obesum*, P; *H. rigdenae*, P; *H. sinistrum*, P; *H. whittingae*, P.

4647

Lat. 4° 33′ S., long. 87° 42′ W. November 9, 1904. Temperature, 70°.
800 fathoms to surface: — *H. rigdenae*, P.

4648

Lat. 4° 43′ S., long. 87° 7′ W. November 9, 1904. Temperature, 71°.
300 fathoms to surface: — *H. whittingae*, P.

4650

Lat. 5° 22′ S., long. 84° 39′ W. November 10, 1904. Temperature, 71°.
300 fathoms to surface: — *H. fenestratum*, P; *H. rigdenae*, P.

4657

Lat. 7° 12′ S., long. 84° 9′ W. November 13, 1904. Temperature, 69°.
300 fathoms to surface: — *H. agassizi*, 1%.

4659

Lat. 8° 54′ S., long. 86° 5′ W. November 14, 1904. Temperature, 69°.
300 fathoms to surface: — *H. fenestratum*, P; *H. rigdenae*, P.

4664

Lat. 11° 30′ S., long. 87° 19′ W. November 17, 1904. Temperature, 68°.
300 fathoms to surface: — *H. rigdenae*, P.

4667

Lat. 11° 59′ S., long. 83° 40′ W. November 18, 1904. Temperature, 68°.
300 fathoms to surface: — *H. murrayi*, P.

4669

Lat. 12° 12′ S., long. 80° 25′ W. November 19, 1904. Temperature, 67°.
Surface: — *H. fenestratum*, P.

4670

Lat. 12° 8′ S., long. 79° 2′ W. November 20, 1904. Temperature, 66°.
800 fathoms to surface: — *H. fenestratum*, P; *H. murrayi*, P.

4676

Lat. 14° 28′ S., long. 81° 24′ W. December 5, 1904. Temperature, 69°.
300 fathoms to surface: — *H. fenestratum*, P; *H. globosum*, P; *H. milneri*, 1%.

4679

Lat. 17° 26′ S., long. 86° 46′ W. December 7, 1904. Temperature, 69°.
300 fathoms to surface: — *H. curvatum*, P; *H. dispar*, P; *H. elongatum*, P; *H. fenestratum*, P; *H. gestieulatum*, P; *H. globosum*, P; *H. milneri*, P; *H. murrayi*, P.

4680

Lat. 17° 55′ S., long. 87° 42′ W. December 7, 1904. Temperature, 68°.
Surface: — *H. curvatum*, P; *H. milneri*, P.

4681

Lat. 18° 47′ S., long. 89° 26′ W. December 8, 1904. Temperature, 68°.
300 fathoms to surface: — *H. agassizi*, P; *H. fenestratum*, P; *H. gesticulatum*, P; *H. scrippsi*, P.
800 fathoms to surface: — *H. elongatum*, P; *H. gesticulatum*, P; *H. milneri*, P; *H. obesum*, 1%; *H. varicator*, P.

4683

Lat. 20° 2′ S., long. 91° 52′ W. December 9, 1904. Temperature, 70°.
300 fathoms to surface: — *H. dispar*, 1%; *H. gesticulatum*, P; *H. milneri*, P; *H. whittingae*, P.

4685

Lat. 21° 36′ S., long. 94° 56′ W. December 10, 1904. Temperature, 72°.
300 fathoms to surface: — *H. dispar*, 1%; *H. milneri*, P.

4686

Lat. 22° 2′ S., long. 95° 52′ W. December 10, 1904. Temperature, 71°.
Surface: — *H. milneri*, P.

4687

Lat. 22° 49′ S., long. 97° 30′ W. December 11, 1904. Temperature, 73°.
300 fathoms to surface: — *H. curvatum*, P; *H. extremum*, P; *H. gesticulatum*, P.

4688

Lat. 23° 17′ S., long. 98° 37′ W. December 11, 1904. Temperature, 72°.
Surface: — *H. curvatum*, P.

4689

Lat. 24° 5′ S., long. 100° 20′ W. December 12, 1904. Temperature, 72°.
300 fathoms to surface: — *H. gesticulatum*, 1%; *H. laeve*, P; *H. mediocre*, 1%.
800 fathoms to surface: — *H. gesticulatum*, 1%; *H. globosum*, P; *H. milneri*, P; *H. whittingae*, P.

4691

Lat. 25° 27′ S., long. 103° 29′ W. December 13, 1904. Temperature, 73°.
300 fathoms to surface: — *H. agassizi*, P; *H. angulatum*, P; *H. asymmetricum*, P; *H. blackmani*, P; *H. calvum*, P; *H. curvatum*, P; *H. dispar*, P; *H. extremum*, P; *H. gesticulatum*, P; *H. globosum*, 1%; *H. hindmarchii*, P; *H. laeve*, P; *H. rigdenae*, P; *H. scrippsi*, P; *H. varicator*, P; *H. whittingae*, 1%.

4692

Lat. 28° 40′ S., long. 104° 1′ W. December 13, 1904. Temperature, 73°.
Surface: — *H. curvatum*, 3%; *H. dispar*, 1%; *H. globosum*, 1%.

4695

Lat. 25° 22′ S., long. 107° 45′ W. December 23, 1904. Temperature, 74°.

300 fathoms to surface: — *H. calvum*, P; *H. dispar*, 1%; *H. doma*, P; *H. gesticulatum*, P; *H. hindmarchii*, P; *H. laeve*, P; *H. rigdenae*, 1%; *H. scrippsi*, P; *H. spiniferum*, P.

4697

Lat. 23° 24′ S., long. 106° 2′ W. December 24, 1904. Temperature, 75°.

300 fathoms to surface: — *H. blackmani*, P; *H. curvatum*, P; *H. doma*, P; *H. gesticulatum*, 1%; *H. globosum*, P; *H. hindmarchii*, P; *H. laeve*, P; *H. laticinctum*, P; *H. leiorhynchum*, P; *H. milneri*, P; *H. minutum*, P; *H. rigdenae*, P; *H. scrippsi*, P; *Dolichodinium lineatum*, P.

4698

Lat. 22° 50′ S., long. 105° 31′ W. December 24, 1904. Temperature, 75°.

Surface: — *Heterodinium curvatum*, 2%.

4699

Lat. 21° 39′ S., long. 104° 29′ W. December 25, 1904. Temperature, 75°.

300 fathoms to surface: — *H. agassizi*, P; *H. asymmetricum*, P; *H. blackmani*, P; *H. curvatum*, P; *H. dispar*, P; *H. doma*, P; *H. extremum*, 3%; *H. gesticulatum*, P; *H. globosum*, P; *H. hindmarchii*, P; *H. laeve*, 1%; *H. mediocre*, P; *H. milneri*, P; *H. rigdenae*, P; *H. superbum*, P; *H. varicator*, P.

4700

Lat. 20° 28′ S., long. 103° 26′ W. December 25, 1904. Temperature, 74°.

Surface: — *H. curvatum*, 1%.

4701

Lat. 19° 11′ S., long. 102° 24′ W. December 26, 1904. Temperature, 72°.

300 fathoms to surface: — *H. agassizi*, P; *H. asymmetricum*, P; *H. blackmani*, P; *H. curvatum*, P; *H. dispar*, 1%; *H. doma*, P; *H. elongatum*, P; *H. expansum*, P; *H. extremum*, P; *H. gesticulatum*, P; *H. globosum*, P; *H. hindmarchii*, P; *H. laeve*, P; *H. mediocre*, P; *H. minutum*, P; *H. obesum*, P; *H. rigdenae*, P; *H. scrippsi*, P; *H. whittingae*, 1%; *Dolichodinium lineatum*, P.

800 fathoms to surface: — *Heterodinium laeve*, P; *H. mediocre*, P; *H. whittingae*, 1%.

4705

Lat. 15° 5′ S., long. 99° 19′ W. December 28, 1904. Temperature, 72°.

300 fathoms to surface: — *H. blackmani*, P; *H. curvatum*, P; *H. dispar*, P; *H. fenestratum*, P; *H. gesticulatum*, P; *H. milneri*, P; *H. varicator*, P.

4706

Lat. 14° 18′ S., long. 98° 45′ W. December 28, 1904. Temperature, 72°.

Surface: — *H. blackmani*, P.

4707

Lat. 12° 33′ S., long. 97° 42′ W. December 29, 1904. Temperature, 72°.

300 fathoms to surface: — *H. blackmani*, 1%; *H. extremum*, P; *H. fides*, P; *H. milneri*, P.

4709

Lat. 10° 15′ S., long. 95° 40′ W. December 30, 1904. Temperature, 72°.

300 fathoms to surface: — *H. agassizi*, P; *H. fenestratum*, P; *H. whittingae*, P.

4711

Lat. 7° 47′ S., long. 94° 5′ W. December 31, 1904. Temperature, 75°.

300 fathoms to surface: — *H. fenestratum*, P; *H. milneri*, P.

4713

Lat. 5° 35′ S., long. 92° 21′ W. January 1, 1905. Temperature, 73°.

300 fathoms to surface: — *H. dispar*, P; *H. expansum*, P.

4715

Lat. 2° 40′ S., long. 90° 19′ W. January 2, 1905. Temperature, 75°.

300 fathoms to surface: — *H. asymmetricum*, P; *H. mediocre*, 1%, *H. rigdenae*, P; *H. whittingae*, 1%.

4717

Lat. 5° 10′ S., long. 98° 56′ W. January 13, 1905. Temperature, 75°.

300 fathoms to surface: — *H. rigdenae* P; *H. whittingae*, P.

4719

Lat. 6° 28′ S., long. 101° 16′ W. January 14, 1905. Temperature, 75°.

300 fathoms to surface: — *H. hindmarchii*, P.

4721

Lat. 8° 7′ S., long. 104° 10′ W. January 15, 1905. Temperature, 75°.

300 fathoms to surface: — *H. calvum*, P; *H. fenestratum*, P.

4722

Lat. 9° 31′ S., long. 106° 30′ W. January 16, 1905. Temperature, 75°.

300 fathoms to surface: — *H. dispar*, P; *H. fenestratum*, P; *H. milneri*, P; *H. murrayi*, P.

4724

Lat. 11° 13′ S., long. 109° 39′ W. January 17, 1905. Temperature, 79°.

300 fathoms to surface: — *H. calvum*, P; *H. dispar*, P; *H. elongatum*, P; *H. fides*, P; *H. gesticulatum*, P; *H. globosum*, P; *H. hindmarchii*, P; *H. laticinctum*, P; *H. milneri*, P; *H. minutum*, P; *H. murrayi*, P.

800 fathoms to surface: — *H. mediocre*, P; *H. milneri*, 1%; *H. rigdenae*, 1%.

4728

Lat. 13° 47′ S., long. 114° 21′ W. January 19, 1905. Temperature, 77°.

300 fathoms to surface: — *H. fides*, P.

4730

Lat. 15° 7′ S., long. 117° 1′ W. January 20, 1905. Temperature, 79°.

300 fathoms to surface: — *H. calvum*, P; *H. fenestratum*, P; *H. laeve*, P; *H. obesum*, P; *H. rigdenae*, P.

4732

Lat. 16° 32′ S., long. 119° 59′ W. January 21, 1905. Temperature, 79°.

300 fathoms to surface: — *H. blackmani*, P; *H. dispar*, P; *H. elongatum*, P; *H. fides*, P; *H. gesticulatum*, P; *H. laticinctum*, P; *H. milneri*, P; *H. obesum*, P; *H. rigdenae*, 1%; *H. scrippsi*, P.

800 fathoms to surface: — *H. rigdenae*, P; *H. scrippsi*, P.

4734

Lat. 17° 36′ S., long. 122° 35′ W. January 22, 1905. Temperature, 81°.

300 fathoms to surface: — *H. blackmani*, P; *H. calvum*, P; *H. deformatum*, P; *H. elongatum*, P; *H. milneri*, P; *H. obesum*, P; *H. rigdenae*, P; *H. varicator*, P.

4736

Lat. 19° 4′ S., long. 125° 5′ W. January 23, 1905. Temperature, 81°.

300 fathoms to surface: — *H. deformatum*, P; *H. fides*, P; *H. scrippsi*, P.

4737

Lat. 19° 57′ S., long. 127° 20′ W. January 24, 1905. Temperature, 81.5°.

100 fathoms to surface: — *H. gesticulatum*, P; *H. globosum*, P; *H. hindmarchii*, P.

300 fathoms to surface: — *H. agassizi*, P; *H. extremum*, P; *H. globosum*, P; *H. laticinctum*, P; *H. rigdenae*, 1%.

4739

Lat. 22° 11′ S., long. 133° 21′ W. January 26, 1905. Temperature, 79°.

300 fathoms to surface: — *H. blackmani*, P; *H. calvum*, P; *H. curvatum*, 1%; *H. laeve*, P; *H. laticinctum*, P; *H. rigdenae*, P; *H. scrippsi*, P.

4740

Lat. 9° 2′ S., long. 123° 20′ W. February 11, 1905. Temperature, 81°.

300 fathoms to surface: — *H. fenestratum*, P; *H. globosum*, P; *H. milneri*, P; *H. praetextum*, P.

4742

Lat. 0° 3′ S., long. 117° 15′ W. February 15, 1905. Temperature, 77°.

300 fathoms to surface: — *H. elongatum*, P; *H. fenestratum*, P; *H. mediocre*, 1%; *H. rigdenae*, 1%.

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EXPLANATION OF THE PLATES

PLATE 1

PLATE 1.

Heterodinium calvum Kofoid; type specimen, fig. 1–2, Station 4691 (300–0 fathoms); fig. 3, Station 4739 (300–0 fathoms).

Heterodinium minutum Kofoid and Michener; type specimen, fig 4, Station 4699 (300–0 fathoms); fig. 5–7, Station 4697 (300–0 fathoms).

Heterodinium doma (Murray and Whitting), fig. 8, 9, Station 4590 (300–0 fathoms).

Fig. 1. *Heterodinium calvum* Kofoid, dorsal view. × 1000.

Fig. 2. The same, ventral view. × 1000.

Fig. 3. The same, right lateral view. Pores drawn on three plates only. × 1000.

Fig. 4. *Heterodinium minutum* Kofoid and Michener, oblique dextroventral view. × 1000.

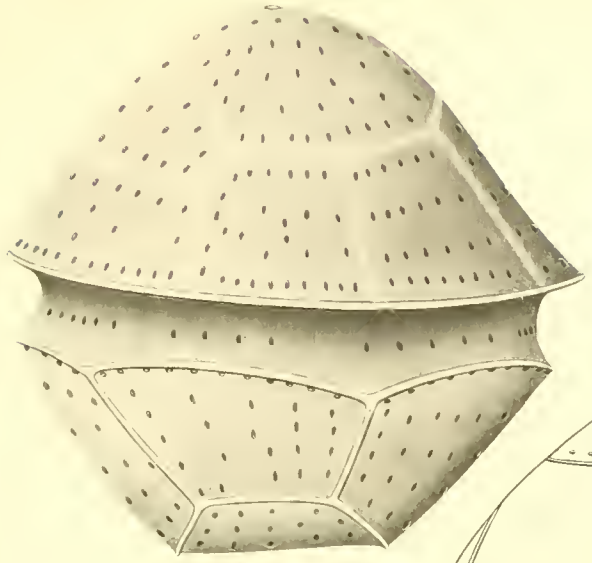
Fig. 5. The same, ventral view. × 1000.

Fig. 6. The same, dorsal view. × 1000.

Fig. 7. The same, transverse optieal section showing nucleus, chromospheres, pusules, apieal pore, and pores in the wall. × 1000.

Fig. 8. *Heterodinium doma* (Murray and Whitting), dorsal view. × 1000.

Fig. 9. The same, ventral view. × 1000.



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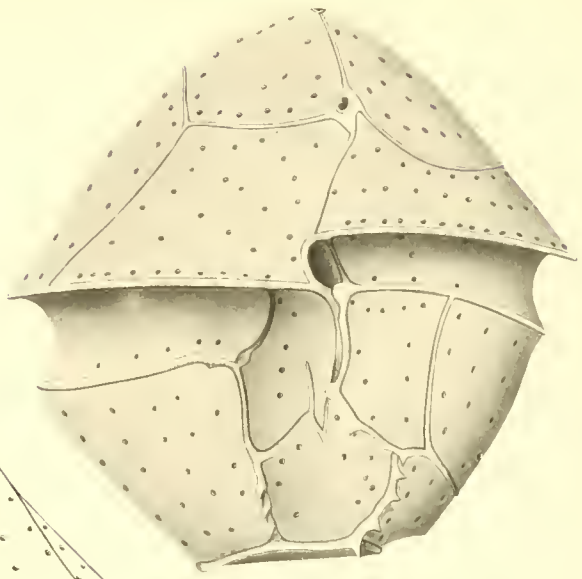

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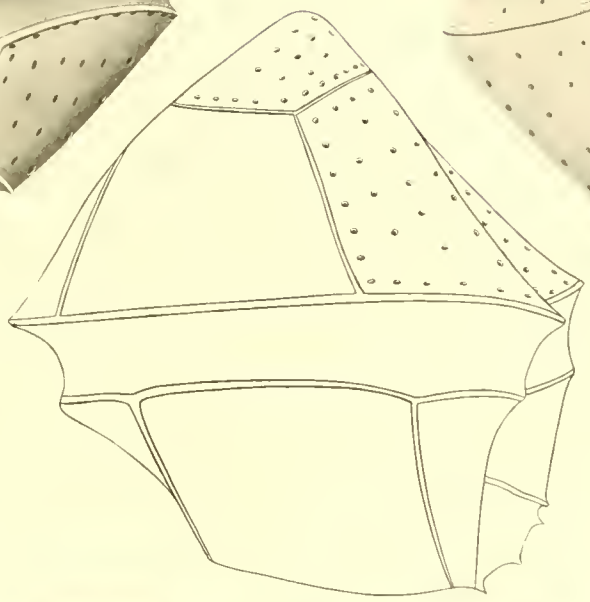

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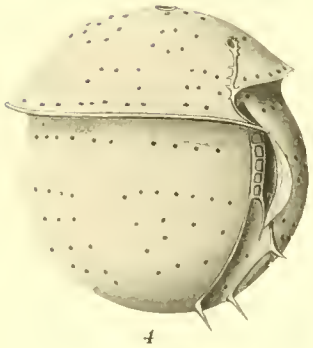

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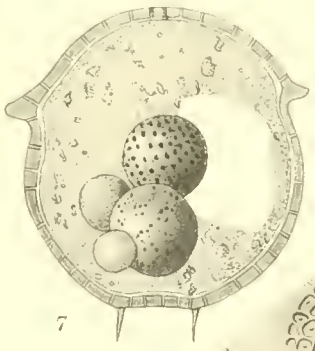

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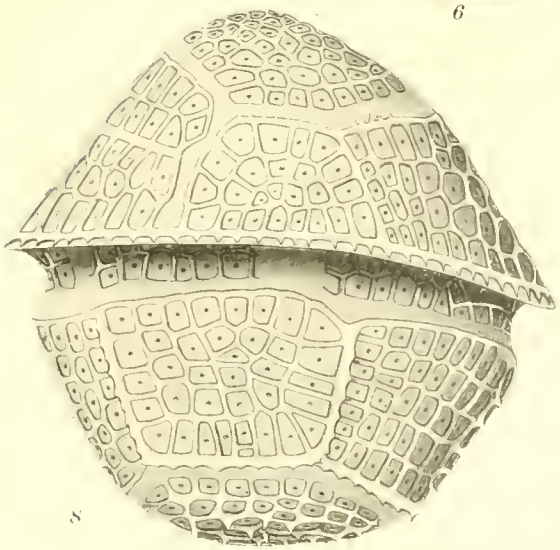

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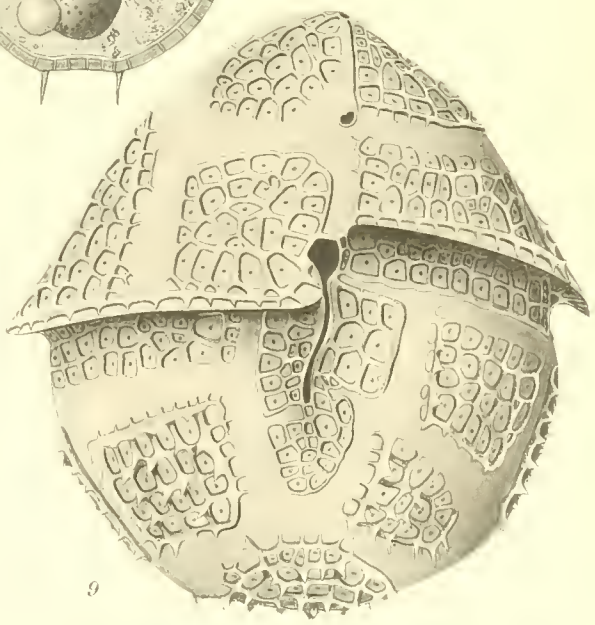

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H. LDTYPE CO.P. BOSTON

PLATE 2

PLATE 2.

Heterodinium murrayi Kofoid; fig. 1–3, Station 4722 (300–0 fathoms).
Heterodinium obesum Kofoid; type specimen, fig. 4–6, Station 4734 (300–0 fathoms).

Fig. 1. *Heterodinium murrayi* Kofoid, ventral view. × 1400.

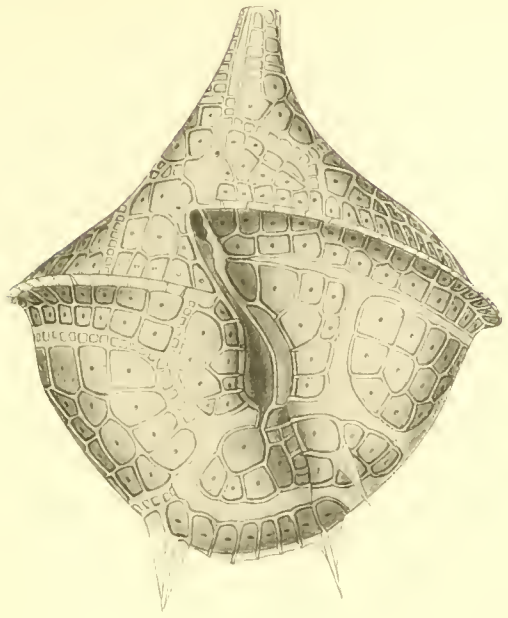
Fig. 2. The same, dorsal view. × 1400.

Fig. 3. The same, cell contents showing three chromospheres, nucleus partly concealed, and many acicular rhabdosomes in the peripheral cytoplasm and also in the cytoplasm extruded through the apical pore. × 1400.

Fig. 4. *Heterodinium obesum* Kofoid, left lateral view. × 1400.

Fig. 5. The same, dorsal view. × 1400.

Fig. 6. The same, ventral view. × 1400.



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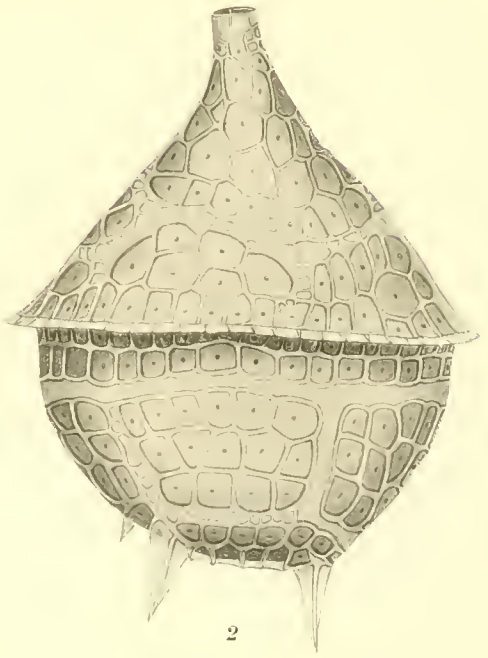

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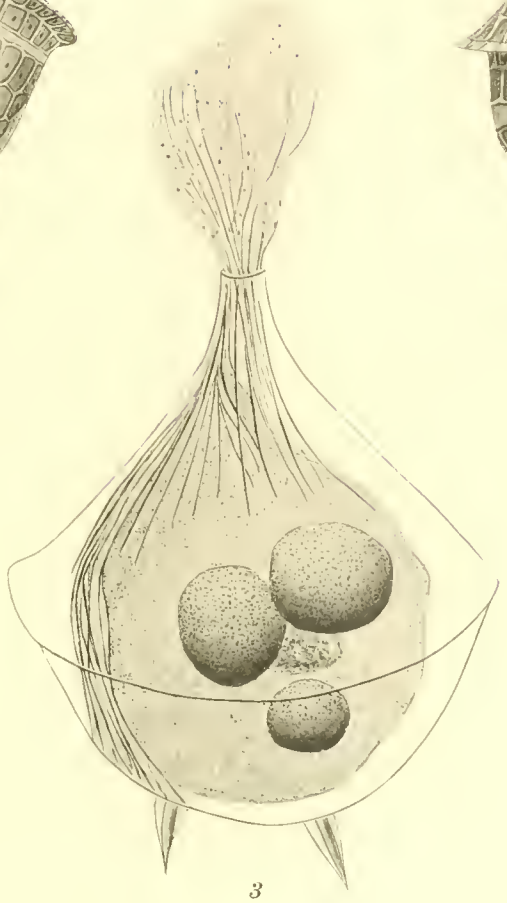

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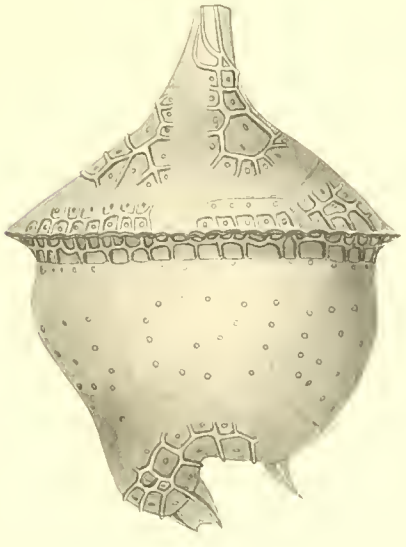

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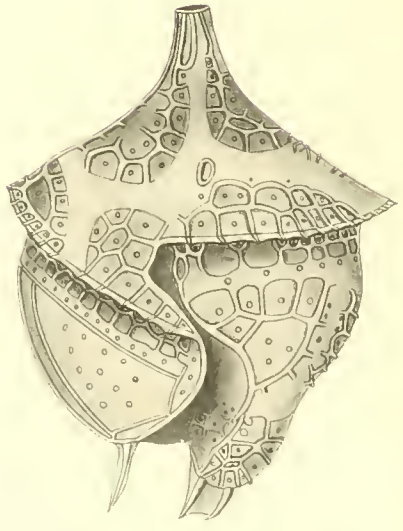

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PLATE 3

PLATE 3.

Heterodinium milneri (Murray and Whitting); fig. 1–2, 4–5, Station 4734 (300–0 fathoms) fig. 6, Station 4722 (300–0 fathoms).
Heterodinium murrayi Kofoid; fig. 3, Station 4722 (300–0 fathoms).

Fig. 1. *Heterodinium milneri* (Murray and Whitting), optical section of cell contents, showing crowded, stout, rod-like, radially arranged, hyaline bodies, clustered chromospheres, and ellipsoidal nucleus. × 1400.

Fig. 2. The same, left lateral view. × 1400.

Fig. 3. *Heterodinium murrayi* Kofoid, left lateral view, showing intercalary bands, reticulations omitted. × 1400.

Fig. 4. *Heterodinium milneri* (Murray and Whitting), dorsal view. × 1400.

Fig. 5. The same, ventral view. × 1400.

Fig. 6. The same, left lateral view of a different specimen from that in Figure 2. × 1400.

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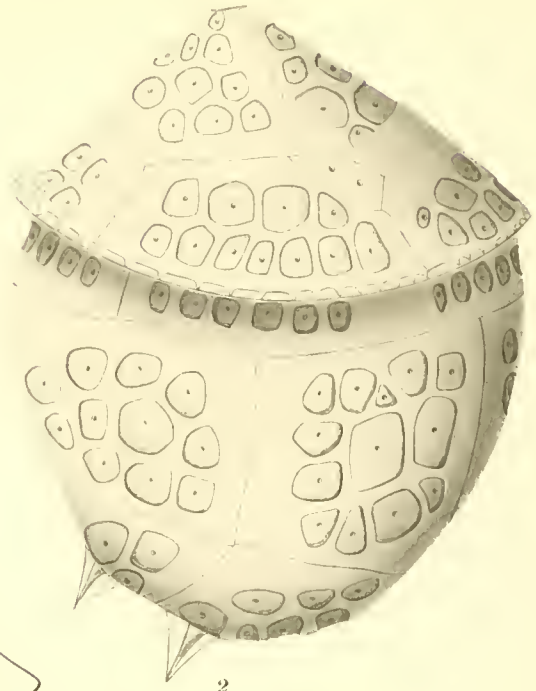

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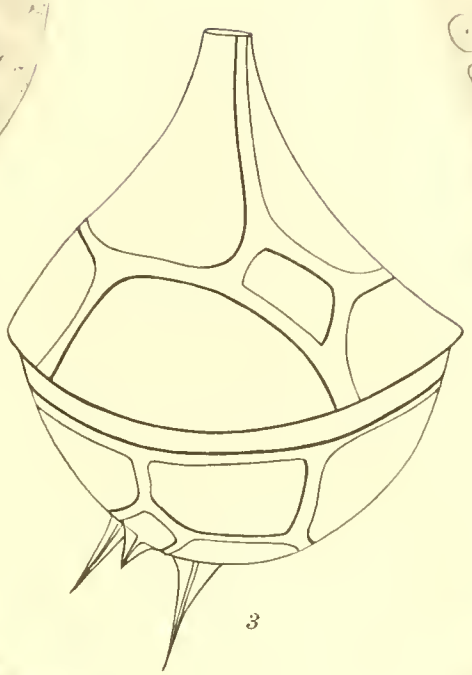

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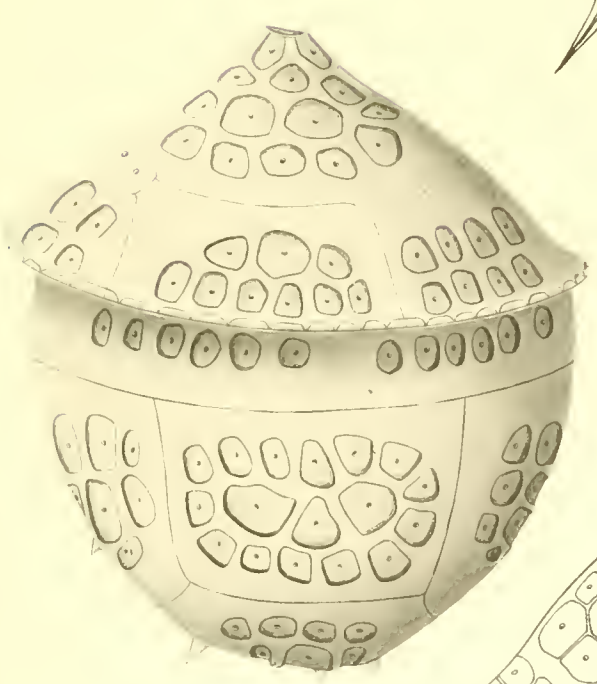

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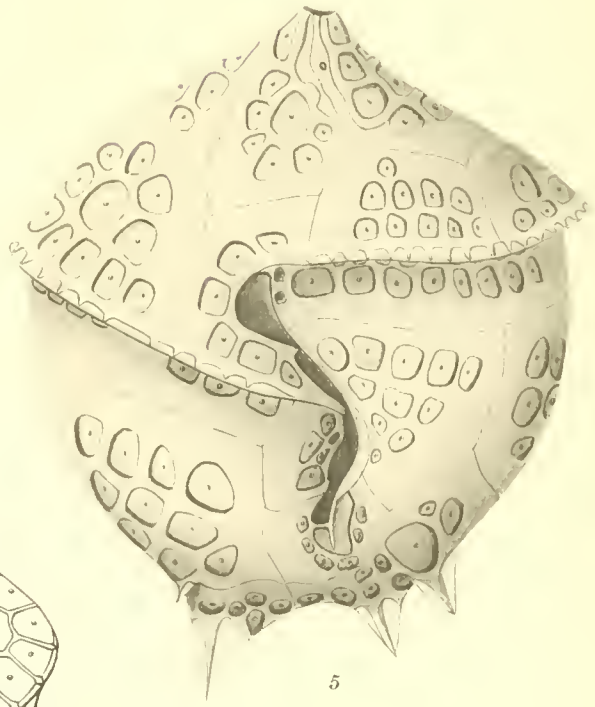

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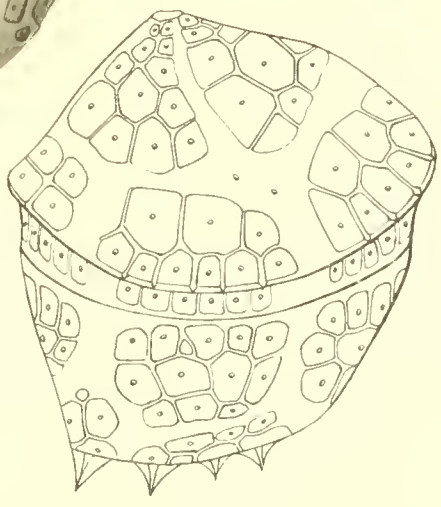

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PLATE 4

PLATE 4.

Heterodinium globosum Kofoid; type specimen, fig. 1–3, Station 4699 (300–0 fathoms); fig. 4, Station 4732 (300–0 fathoms).

Heterodinium superbum Kofoid; type specimen, fig. 5–7, Station 4699 (300–0 fathoms).

Fig. 1. *Heterodinium globosum* Kofoid, dorsal view. × 607.

Fig. 2. The same, left lateral view. × 607.

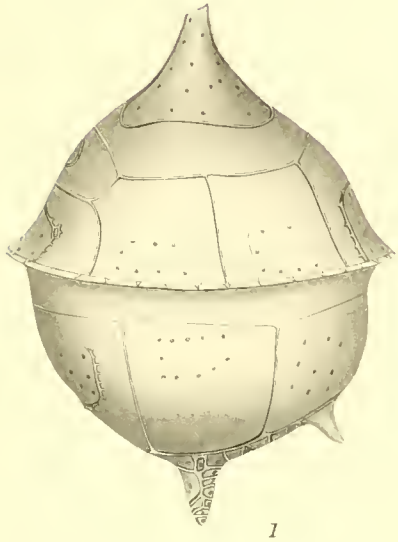
Fig. 3. The same, ventral view. × 607.

Fig. 4. The same, ventral view of a variant with greater inequality of antapicals, and different apical and ventral pores. × 607.

Fig. 5. *Heterodinium superbum* Kofoid, dorsal view. × 1000.

Fig. 6. The same, left dorsolateral view. × 1000.

Fig. 7. The same, ventral view. × 1000.



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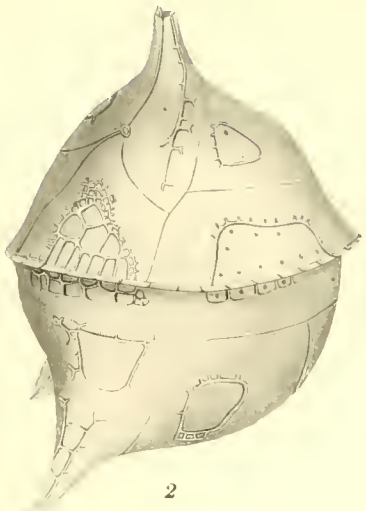

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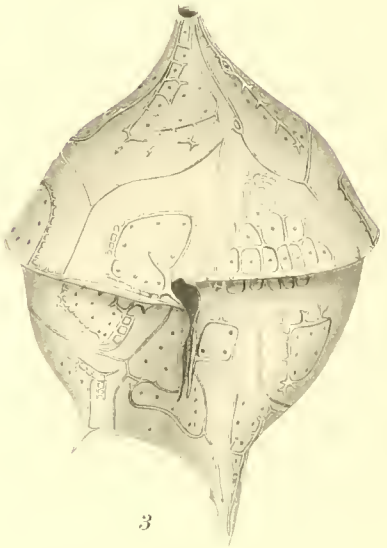

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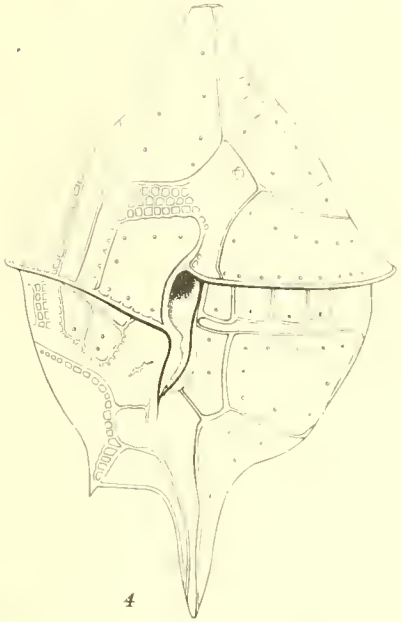

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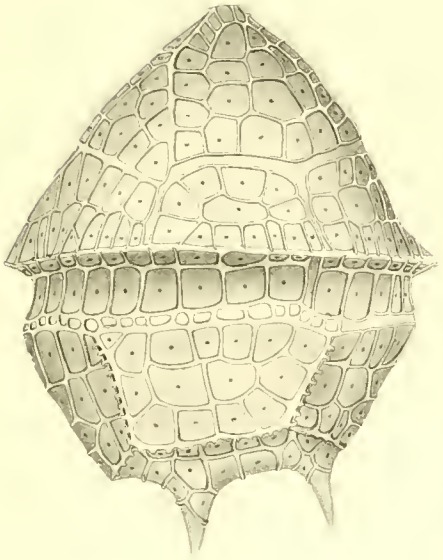

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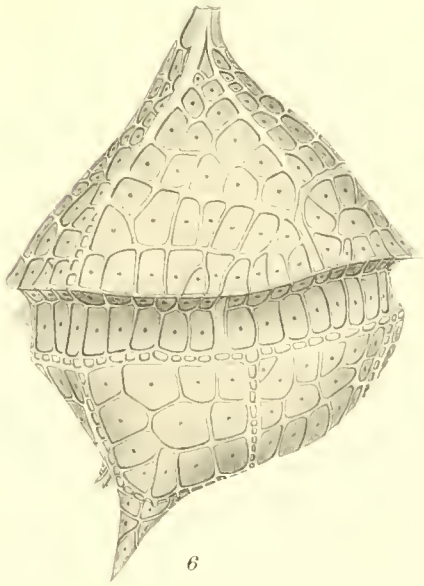

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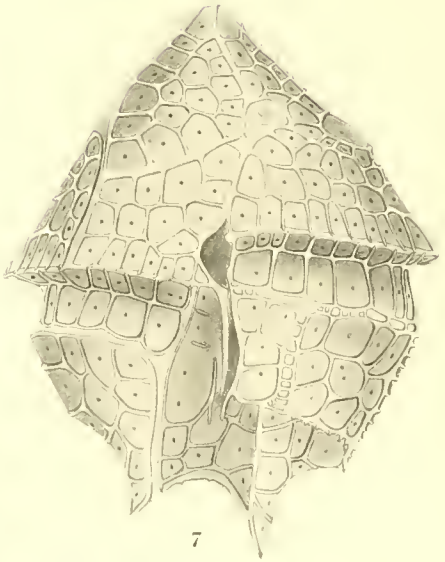

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PLATE 5

PLATE 5.

Heterodinium scrippsi Kofoid; fig. 1, Station 4734 (300–0 fathoms).
Heterodinium dispar sp. nov.; type specimen, fig. 2, 3, Station 4683 (300–0 fathoms).
Heterodinium rigdenae Kofoid; fig. 4, Station 4737 (300–0 fathoms).
Heterodinium expansum Kofoid; type specimen, fig. 5–7, Station 4637 (300–0 fathoms).

Fig. 1. *Heterodinium scrippsi* Kofoid, ventral view. × 850.
Fig. 2. *Heterodinium dispar* Kofoid, dorsal view. × 1400.
Fig. 3. The same, ventral view. × 1400.
Fig. 4. *Heterodinium rigdenae* Kofoid, ventral view. Specimen with secondary reticulations in intercalary zone prior to ecdysis. × 675.
Fig. 5. *Heterodinium expansum* Kofoid, ventral view. × 850.
Fig. 6. The same, right lateral view, reticulations omitted. × 675.
Fig. 7. The same, dorsal view. × 850.

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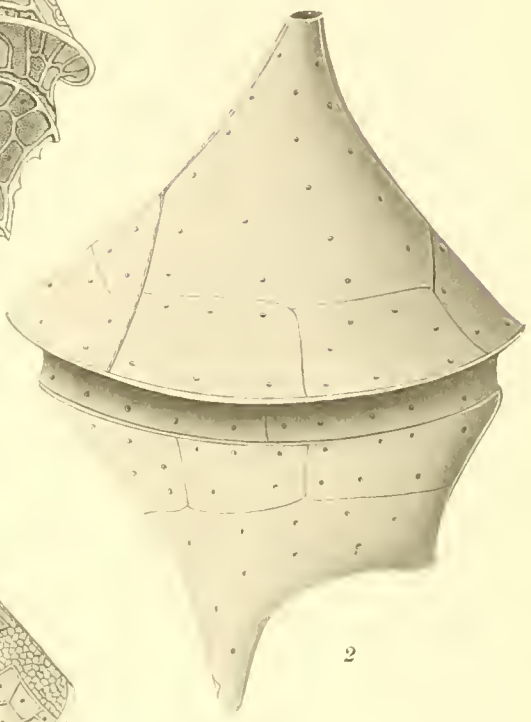

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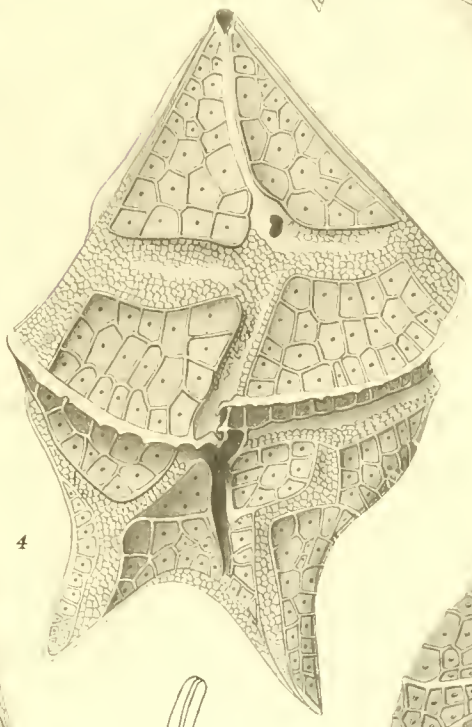

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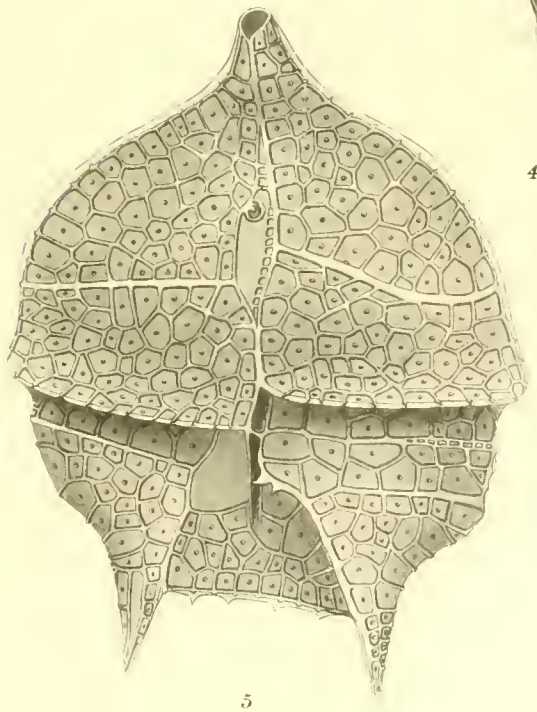

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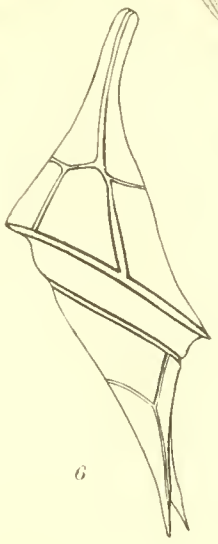

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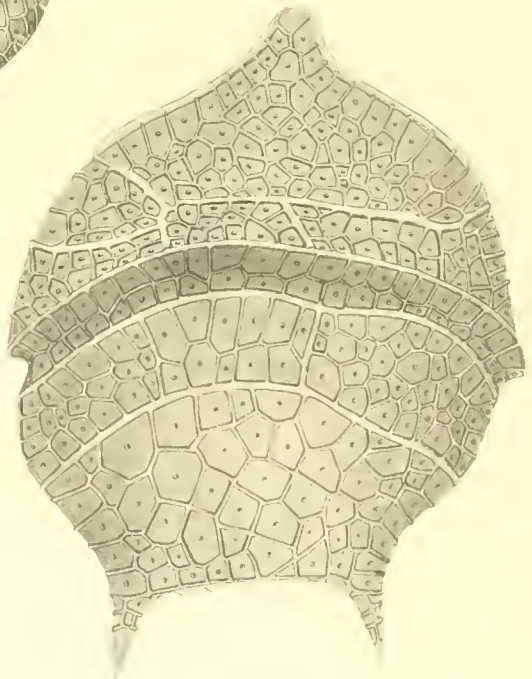

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PLATE 6

PLATE 6.

Heterodinium angulatum Kofoid and Michener; type specimen, fig. 1, 2, Station 4691 (300–0 fathoms).

Heterodinium curvatum Kofoid; type specimen, fig. 3, Station 4699 (300–0 fathoms).

Heterodinium spiniferum Kofoid and Michener; type specimen, fig. 4–6, Station 4696 (300–0 fathoms).

Fig. 1. *Heterodinium angulatum* Kofoid and Michener, dorsal view. × 1000.

Fig. 2. The same, right lateral view, reticulations omitted. × 1000.

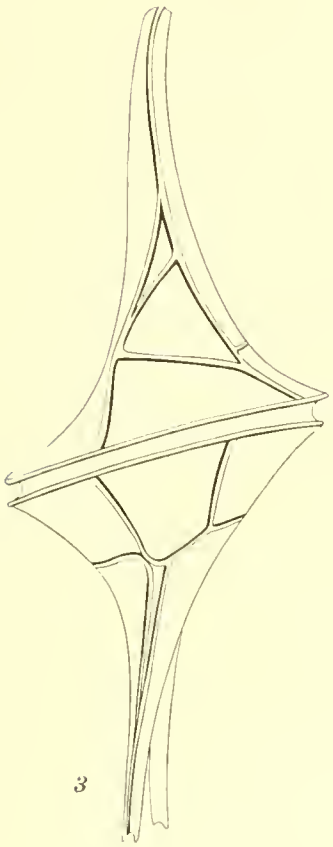
Fig. 3. *Heterodinium curvatum* Kofoid, left lateral view, reticulations omitted. × 482

Fig. 4. *Heterodinium spiniferum* Kofoid and Michener, left lateral view, reticulations omitted. × 1000.

Fig. 5. The same, dorsal view. × 1000.

Fig. 6. The same, ventral view. × 1000.

1



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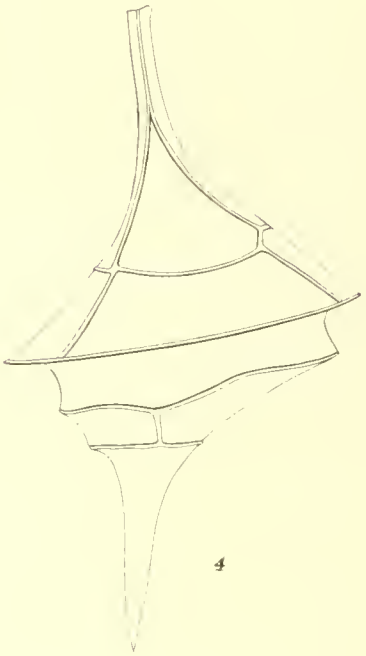

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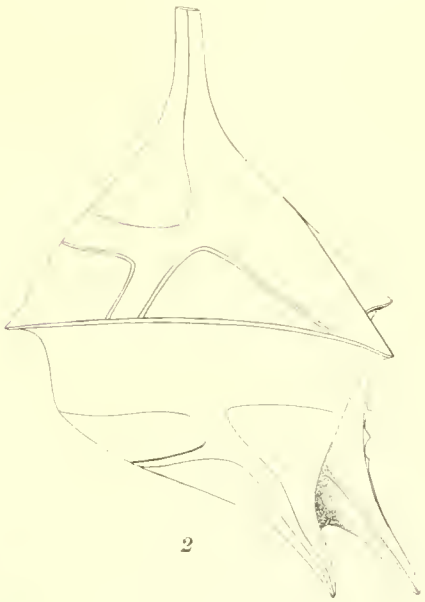

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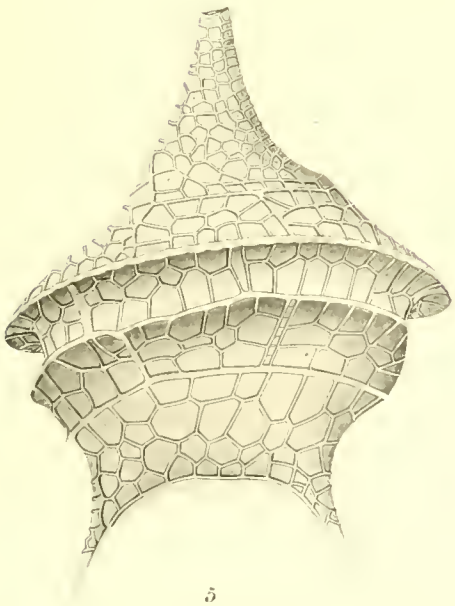

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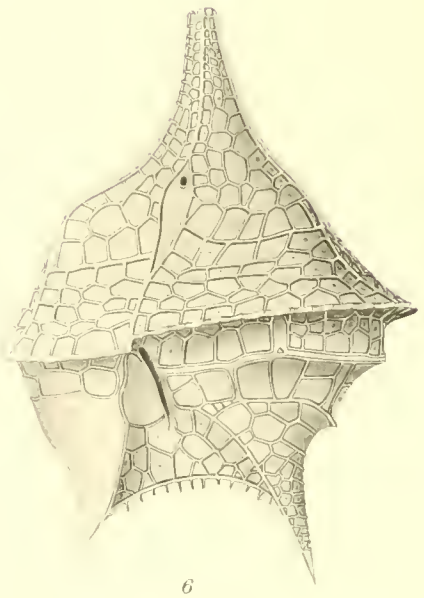

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PLATE 7

PLATE 7.

Heterodinium fenestratum Kofoid; type specimen, fig. 1, 4–6, Station 4730 (300–0 fathoms).
Heterodinium praetextum Kofoid; type specimen, fig. 2, 3, Station 4740 (300–0 fathoms).

Fig. 1. *Heterodinium fenestratum* Kofoid, left dorsolateral view, reticulations omitted. × 1000.

Fig. 2. *Heterodinium praetextum* Kofoid, oblique sinistroventral view, reticulations omitted. × 482.

Fig. 3. The same, ventral view. × 482.

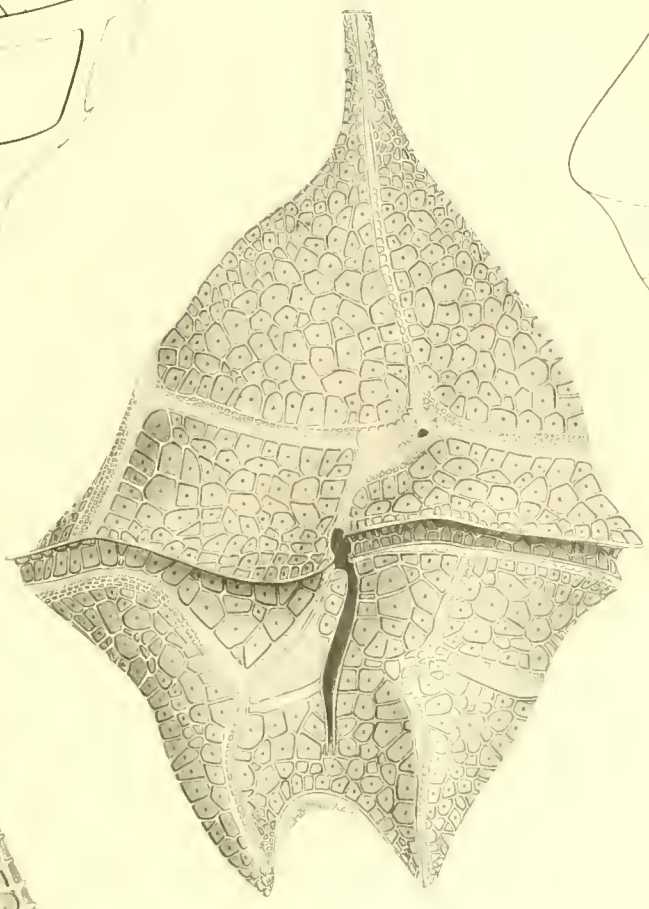
Fig. 4. *Heterodinium fenestratum* Kofoid, dorsal view. × 1000.

Fig. 5. The same, optical section of cell contents showing subventral spherical nucleus, ellipsoidal chromosphere, tubular structure connecting with the ventral pore, and large pusule opening into the apical pore. × 482.

Fig. 6. The same, surface view of the ventral face. × 1000.

1

2



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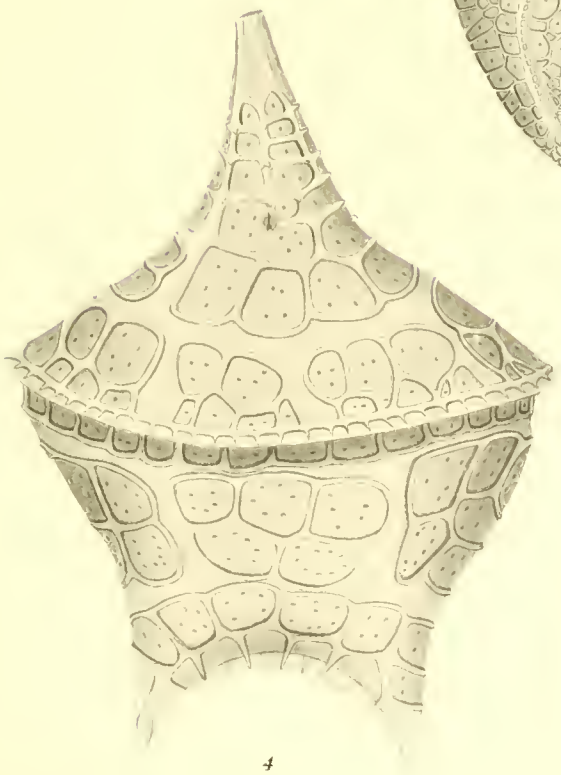

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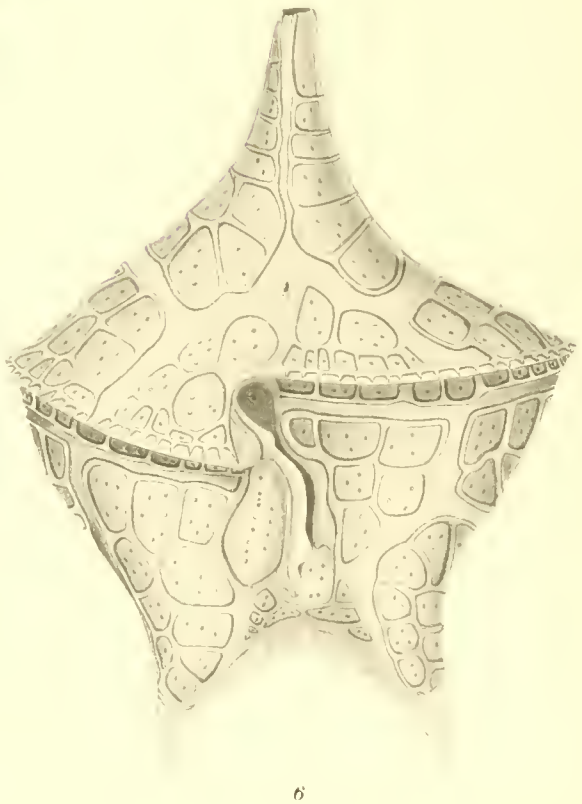

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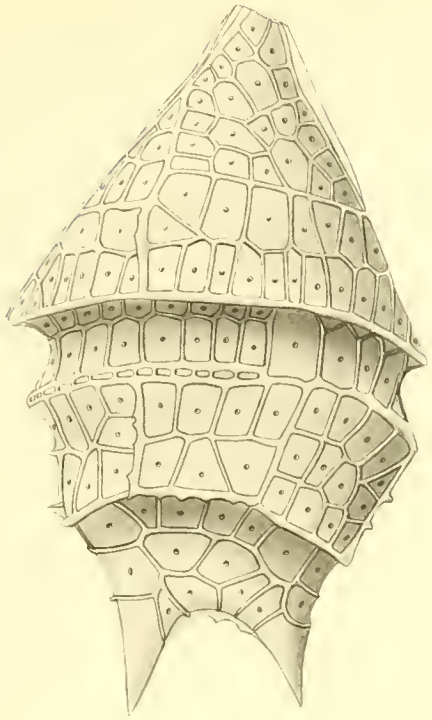
PLATE 8

PLATE 8.

Heterodinium elongatum Kofoid and Michener; type specimen, fig. 1–2, Station 4724 (300–0 fathoms); fig. 3, Station 4732 (300–0 fathoms).
Heterodinium curvatum Kofoid; type specimen, fig. 4, 6, Station 4699 (300–0 fathoms).
Heterodinium hindmarchii (Murray and Whitting); fig. 5, 7, Station 4691 (300–0 fathoms).

Fig. 1. *Heterodinium elongatum* Kofoid and Michener, dorsal view. × 1400.
Fig. 2. The same, left lateral view, reticulations omitted. × 1400.
Fig. 3. The same, ventral view. × 1400.
Fig. 4. *Heterodinium curvatum* Kofoid, left lateral view, reticulations omitted. × 440.
Fig. 5. *Heterodinium hindmarchii* (Murray and Whitting), dorsal view. × 850.
Fig. 6. *Heterodinium curvatum* Kofoid, oblique apical view, reticulations omitted. × 440.
Fig. 7. *Heterodinium hindmarchii* (Murray and Whitting), ventral view. × 850.



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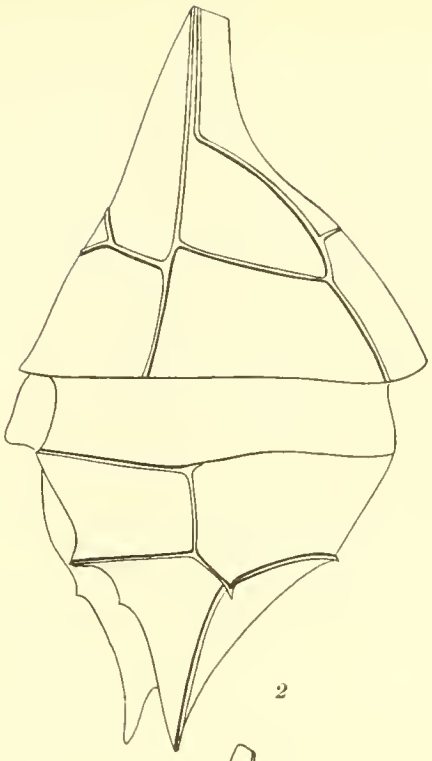

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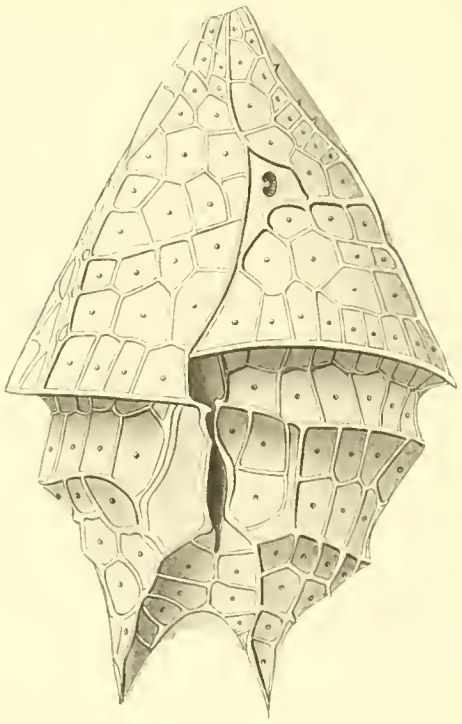

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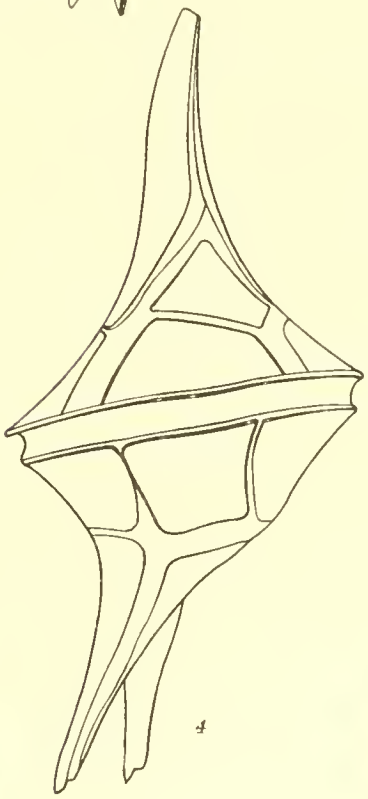

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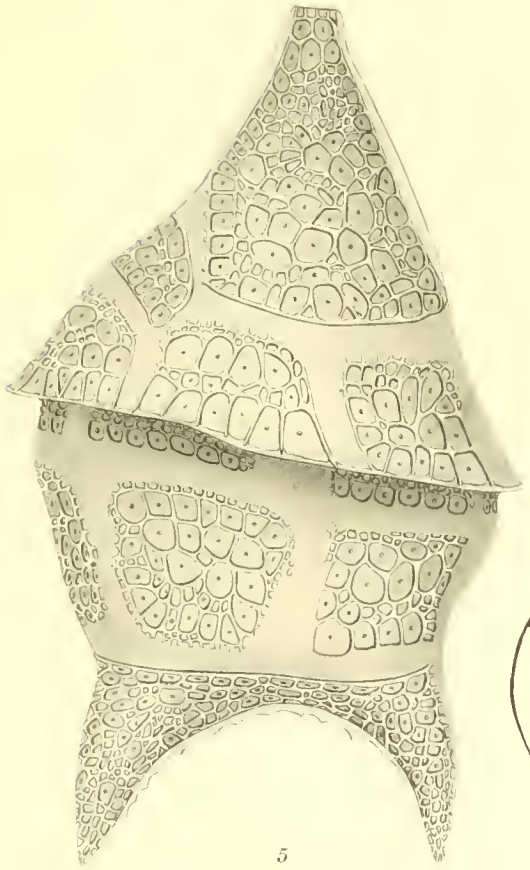

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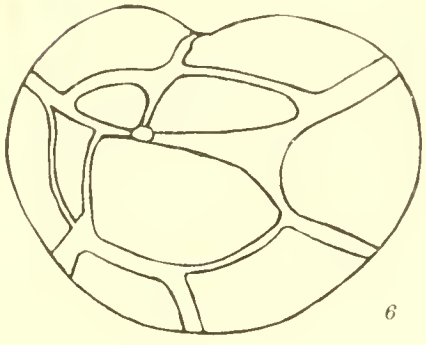

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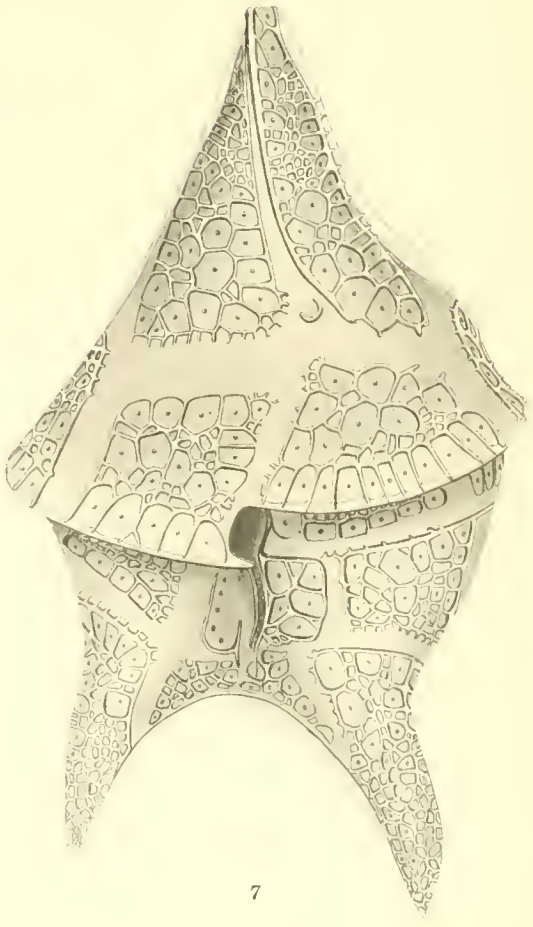

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PLATE 9

PLATE 9.

Heterodinium blackmani (Murray and Whitting); fig. 1, Station 4739 (300–0 fathoms); fig. 2, 3, Station 4699 (300–0 fathoms); fig. 4, 7, Station 4724 (800–0 fathoms).
Heterodinium curvatum Kofoid; type specimen, fig. 5, 6, 8, Station 4699 (300–0 fathoms).

Fig. 1. *Heterodinium blackmani* (Murray and Whitting), dorsal view, reticulations omitted. × 482.

Fig. 2. The same, first precingular plate, with platelet containing the ventral area and ventral pore, attached. × 482.

Fig. 3. The same, sulcus and adjacent area. Postcingular plate 7″′ has an oblique reticular bar crossing its surface. Station 4699 (300–0 fathoms). × 643.

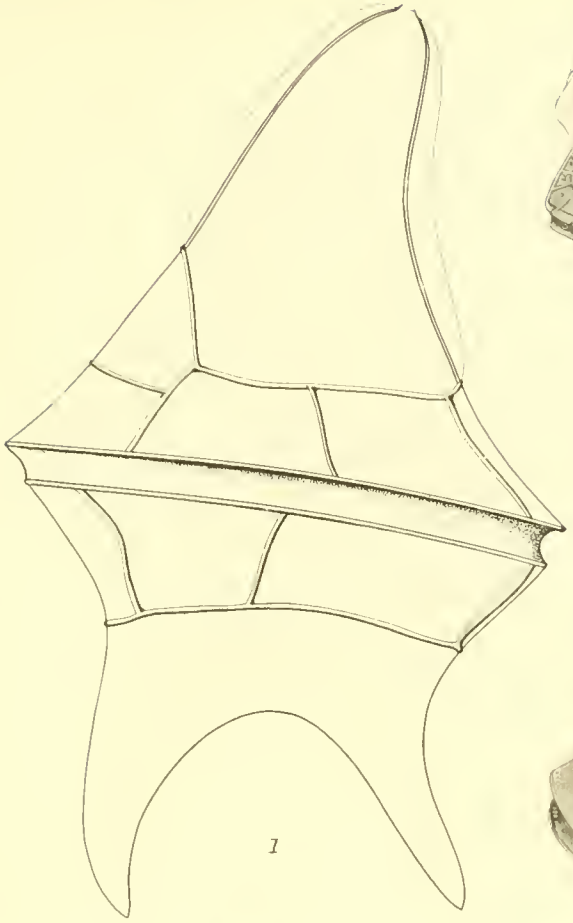
Fig. 4. The same, ventral view. × 482.

Fig. 5. *Heterodinium curvatum* Kofoid, right lateral view. × 482.

Fig. 6. The same, ventral view. × 482.

Fig. 7. *Heterodinium blackmani* (Murray and Whitting), sulcus and adjacent region. × 1000.

Fig. 8. *Heterodinium curvatum* Kofoid, dorsal view. × 482.



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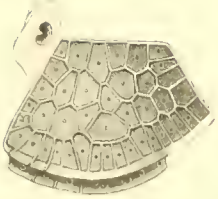

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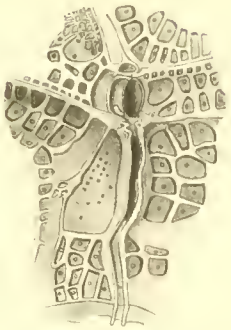

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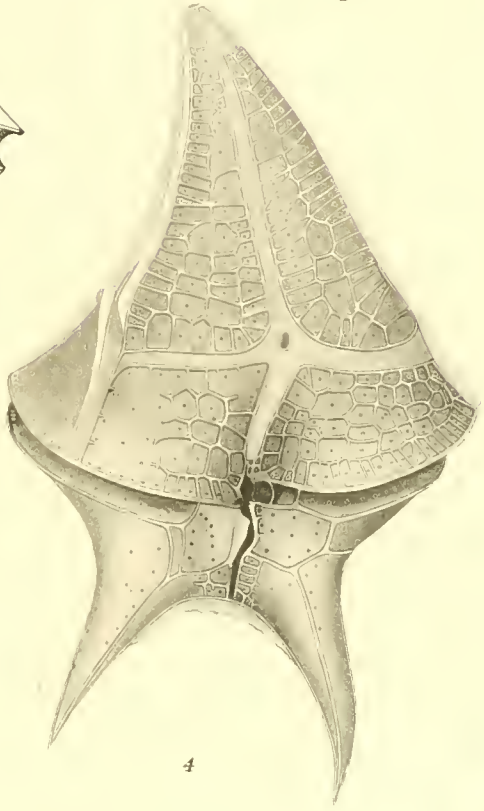

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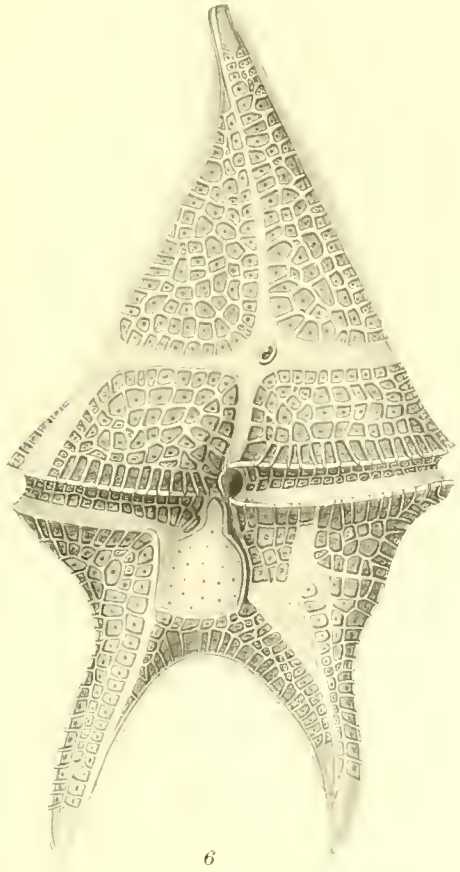

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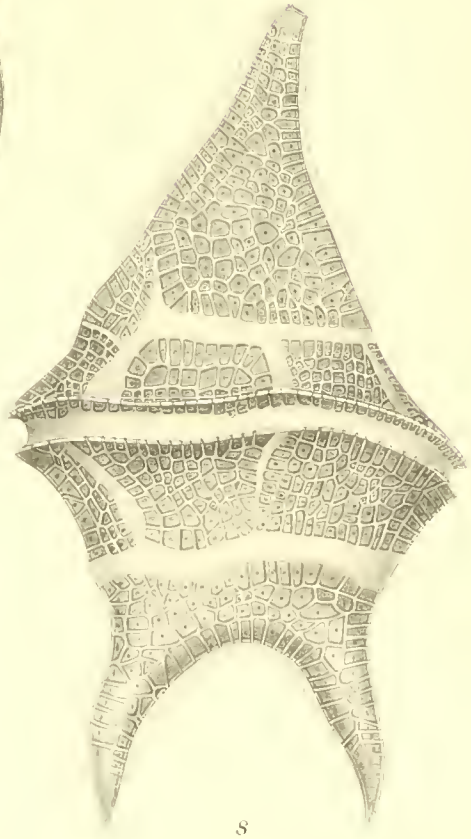

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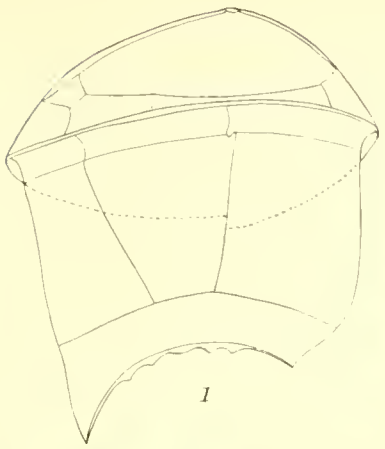
PLATE 10

PLATE 10.

Heterodinium asymmetricum sp. nov.; type specimen, fig. 1, 2, Station 4699 (300–0 fathoms).
Heterodinium laticinctum Kofoid; type specimen, fig. 3, Station 4724 (300–0 fathoms).
Heterodinium agassizi Kofoid; type specimen, fig. 4–8, Station 4699 (300–0 fathoms).

Fig. 1. *Heterodinium asymmetricum* sp. nov., dorsal view. × 675.
Fig. 2. The same, right lateral view. × 675.
Fig. 3. *Heterodinium laticinctum* Kofoid, dorsal view. × 675.
Fig. 4. *Heterodinium agassizi* Kofoid, region of ventral area with ventral pore. × 1400.
Fig. 5. The same, region of sulcus. × 1400.
Fig. 6. The same, dorsal view. × 675.
Fig. 7. The same, left lateral view. × 675.
Fig. 8. The same, ventral view. × 675.



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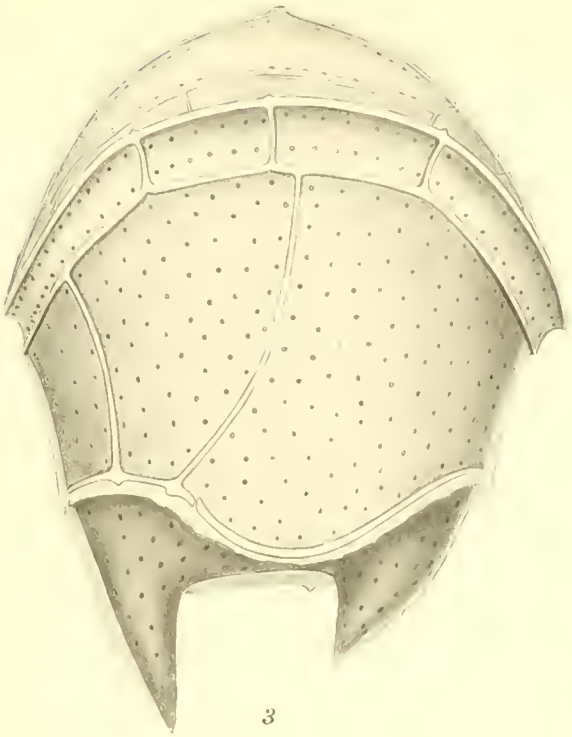

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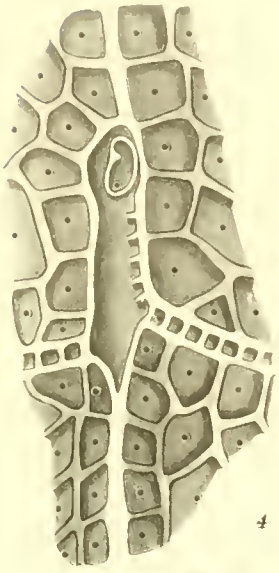

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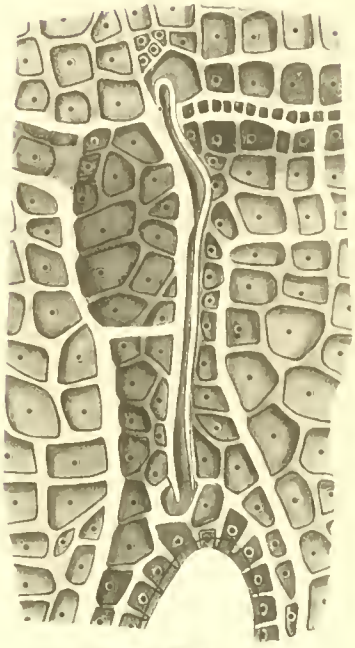

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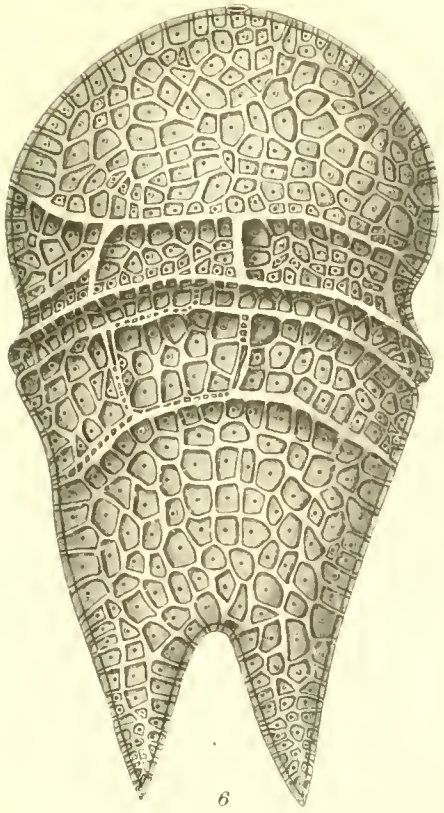

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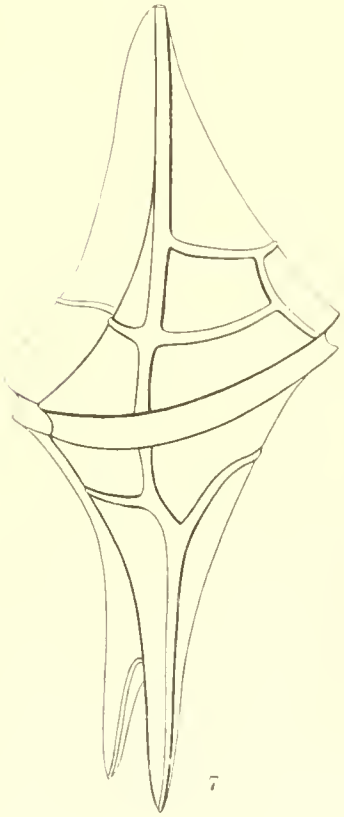

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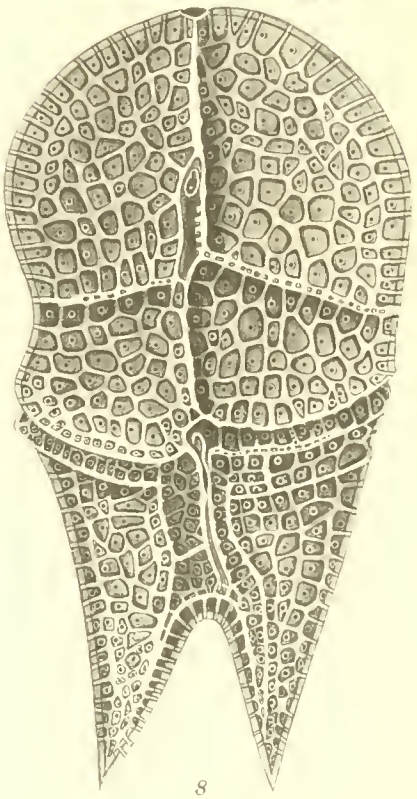

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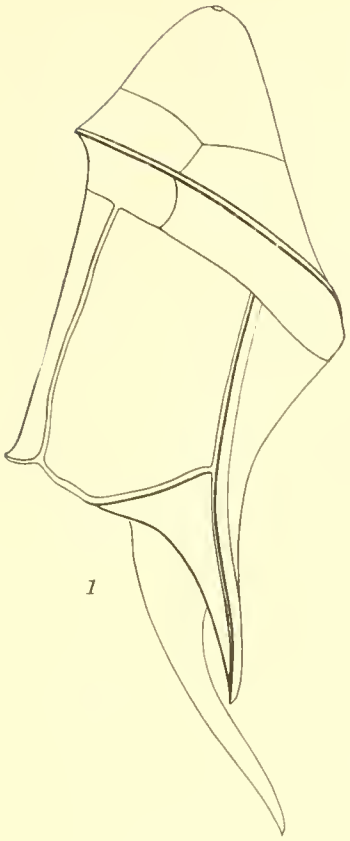
PLATE 11

PLATE 11.

Heterodinium laeve Kofoid and Michener; type specimen, fig. 1, 3, 5, 7, Station 4739 (300–0 fathoms).

Heterodinium fides Kofoid; type specimen, fig. 2, 4, 6, Station 4728 (300–0 fathoms).

Fig. 1. *Heterodinium laeve* Kofoid and Michener, right lateral view. × 675.
Fig. 2. *Heterodinium fides* Kofoid, ventral view. × 675.
Fig. 3. *Heterodinium laeve* Kofoid and Michener, left lateral view. × 675.
Fig. 4. *Heterodinium fides* Kofoid, right lateral view. × 675.
Fig. 5. *Heterodinium laeve* Kofoid and Michener, ventral view. × 675.
Fig. 6. *Heterodinium fides* Kofoid, left lateral view. × 675.
Fig. 7. *Heterodinium laeve* Kofoid and Michener, dorsal view. × 675.



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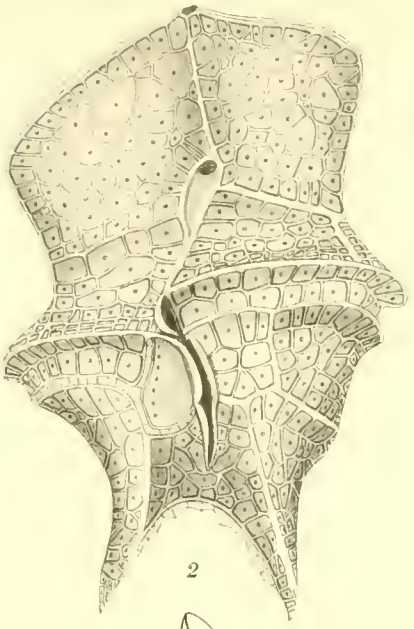

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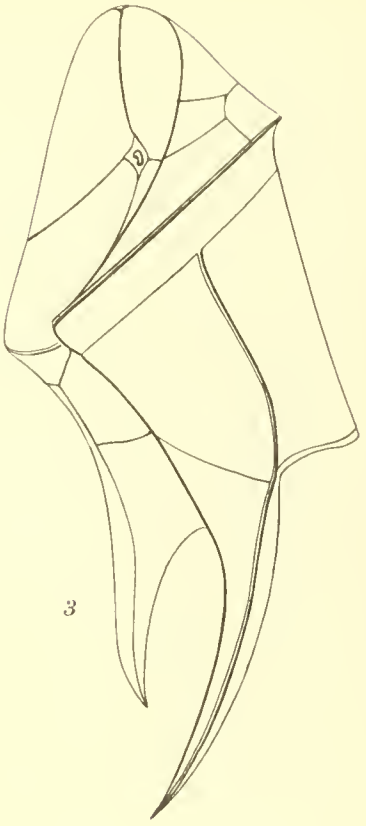

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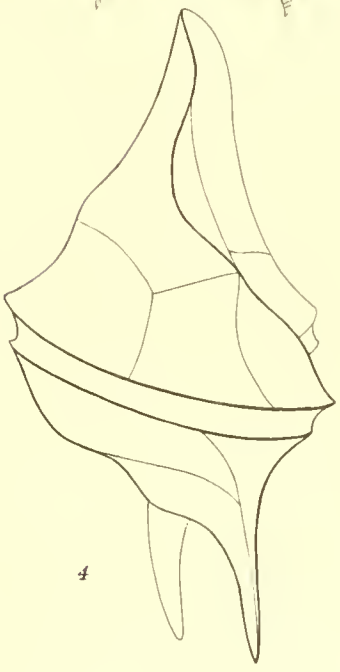

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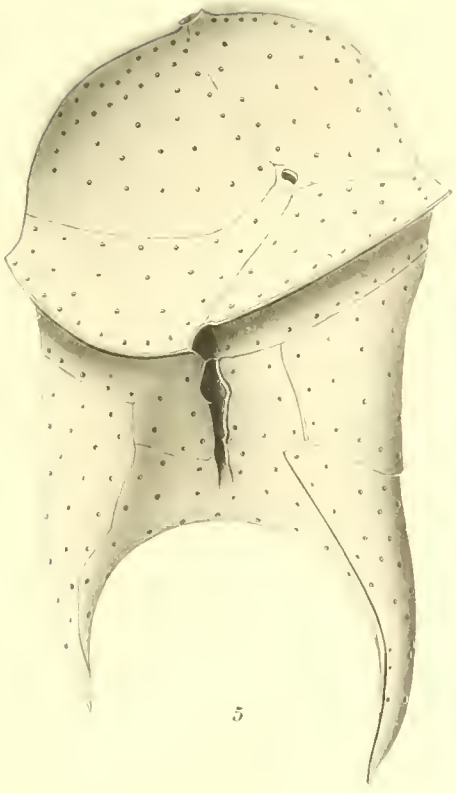

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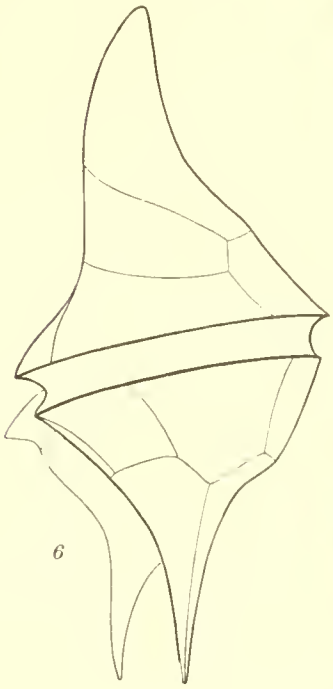

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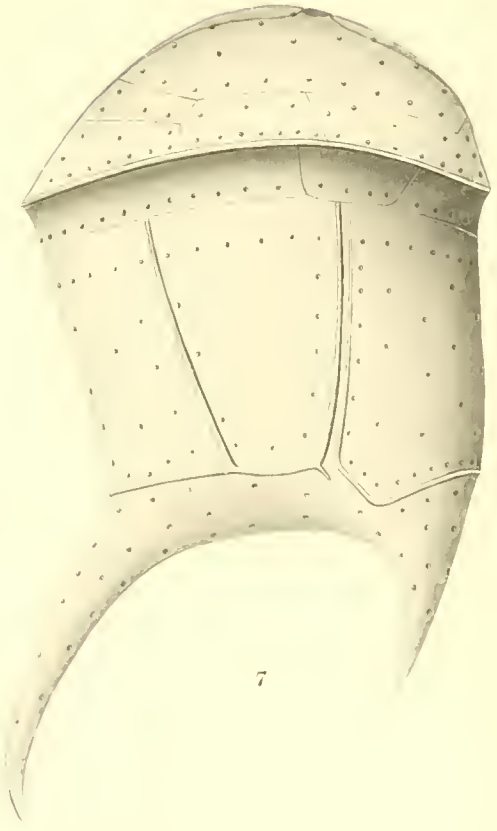

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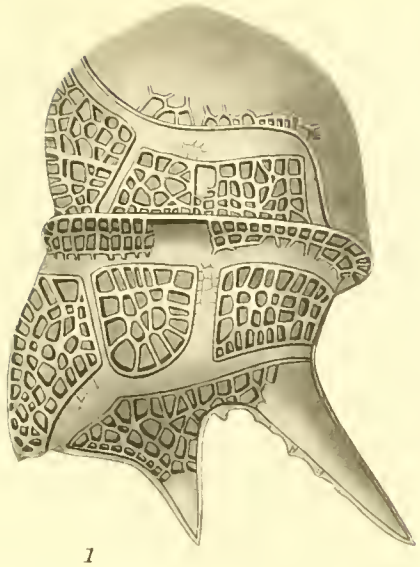
PLATE 12

PLATE 12.

Heterodinium gesticulatum Kofoid; type specimen, fig. 1–5, Station 4594 (300–0 fathoms).
Dolichodinium lineatum (Kofoid and Michener); type specimen, fig. 6–8, Station 4701 (300–0 fathoms).

Fig. 1. *Heterodinium gesticulatum* (Kofoid), dorsal view. × 440.
Fig. 2. The same, left lateral view. × 440.
Fig. 3. The same, ventral view. × 440.
Fig. 4. The same, ventral area. × 900.
Fig. 5. The same, sulcus and adjacent regions. × 900.
Fig. 6. *Dolichodinium lineatum* (Kofoid and Michener), left lateral view. × 1400.
Fig. 7. The same, dorsal view. × 1400.
Fig. 8. The same, ventral view. × 1400.



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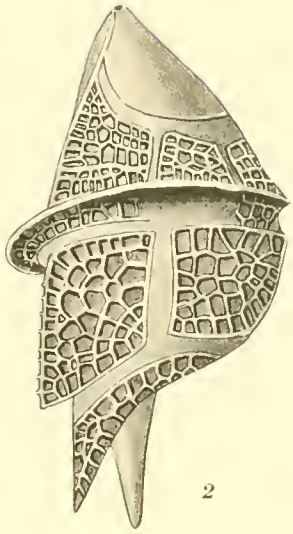

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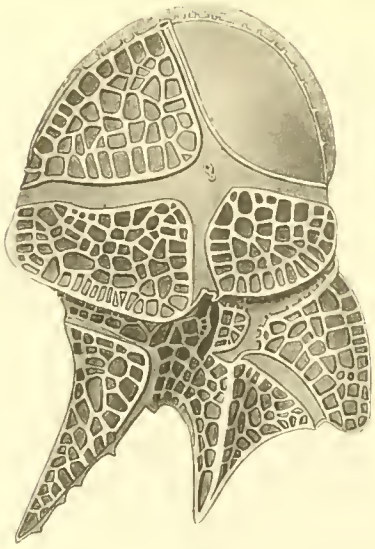

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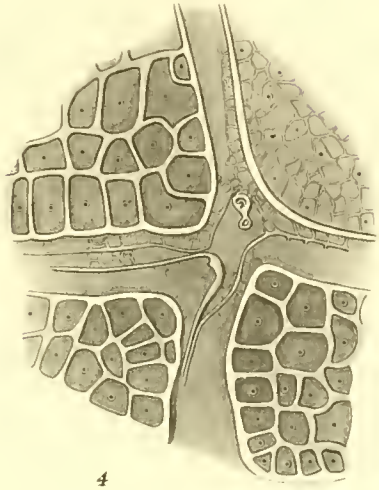

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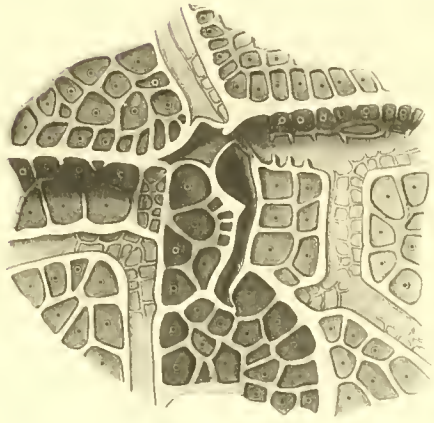

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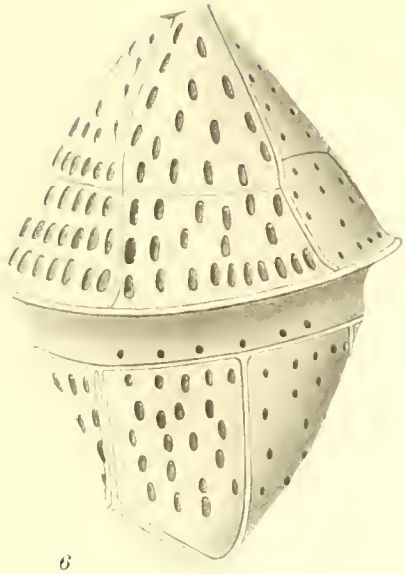

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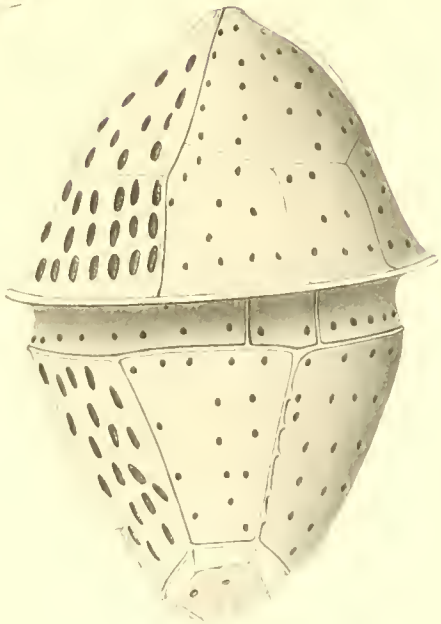

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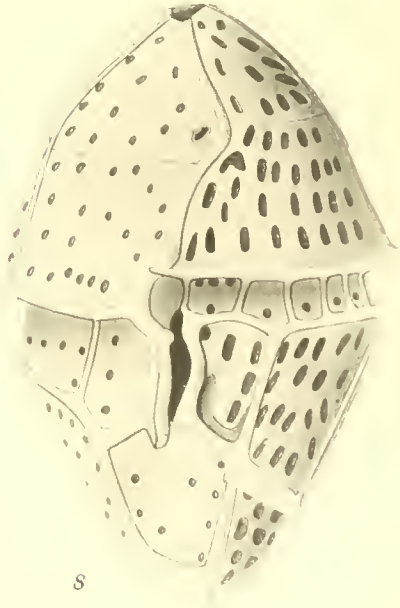

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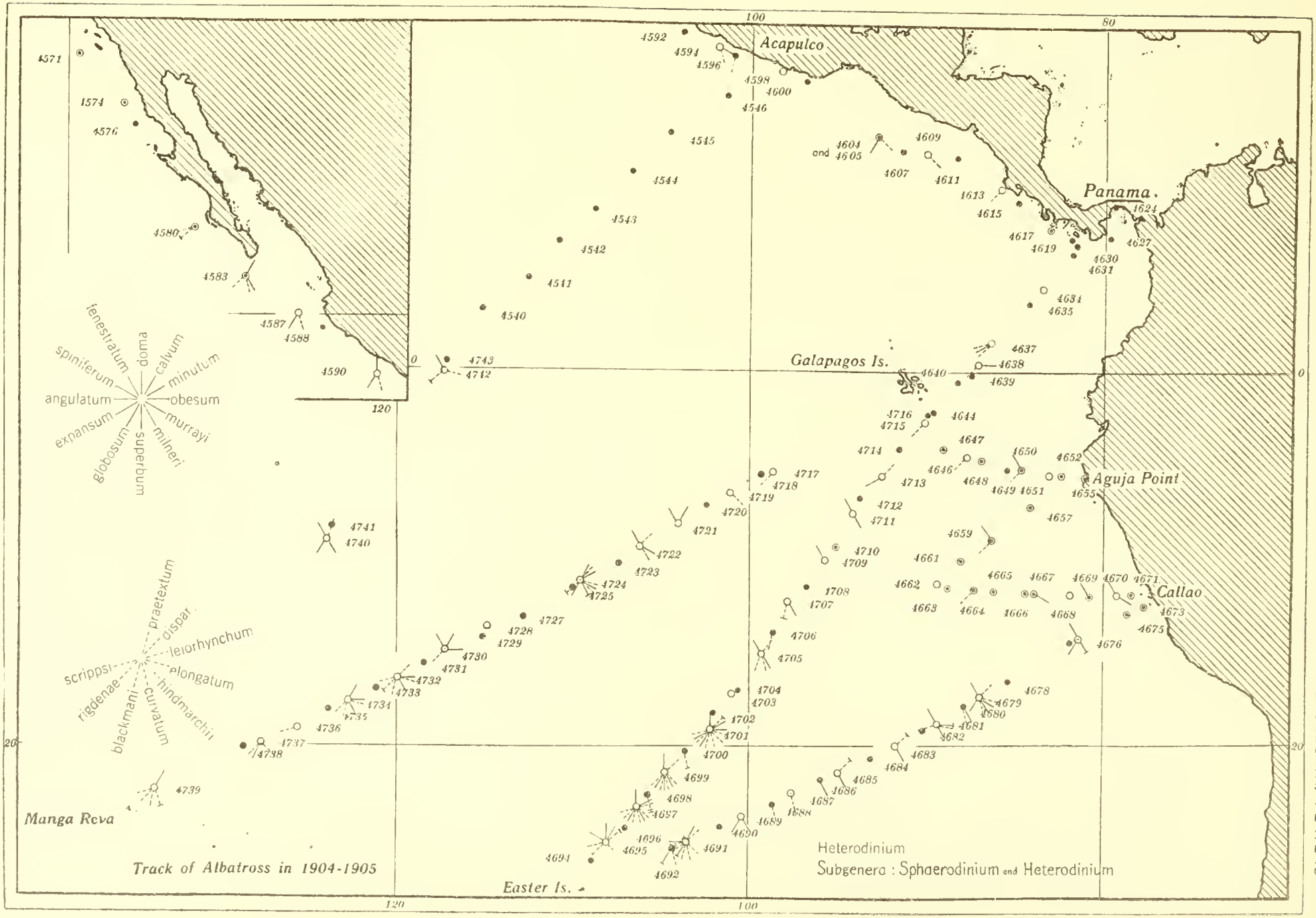
PLATE 13

PLATE 13.

Map of distribution of species of Heterodinium belonging to the subgenera Sphaerodinium and Heterodinium. Species of Sphaerodinium are represented by solid lines, and species of Heterodinium by dotted lines. All record stations are marked by circles on the lines of the route. Solid circles indicate surface hauls; open circles, vertical hauls; open circles including solid circles, vertical and surface hauls at the same station. The occurrences of the species at the various stations are indicated by radii, the keys to which are to be found in the key stars on the left side of the chart. The frequencies are indicated by Roman numerals at the distal ends of the radii; these numerals should be read from the distal toward the proximal end of the radius. Absence of Roman numerals indicates that the species were "present" (*i.e.*, frequency of less than 1%.)

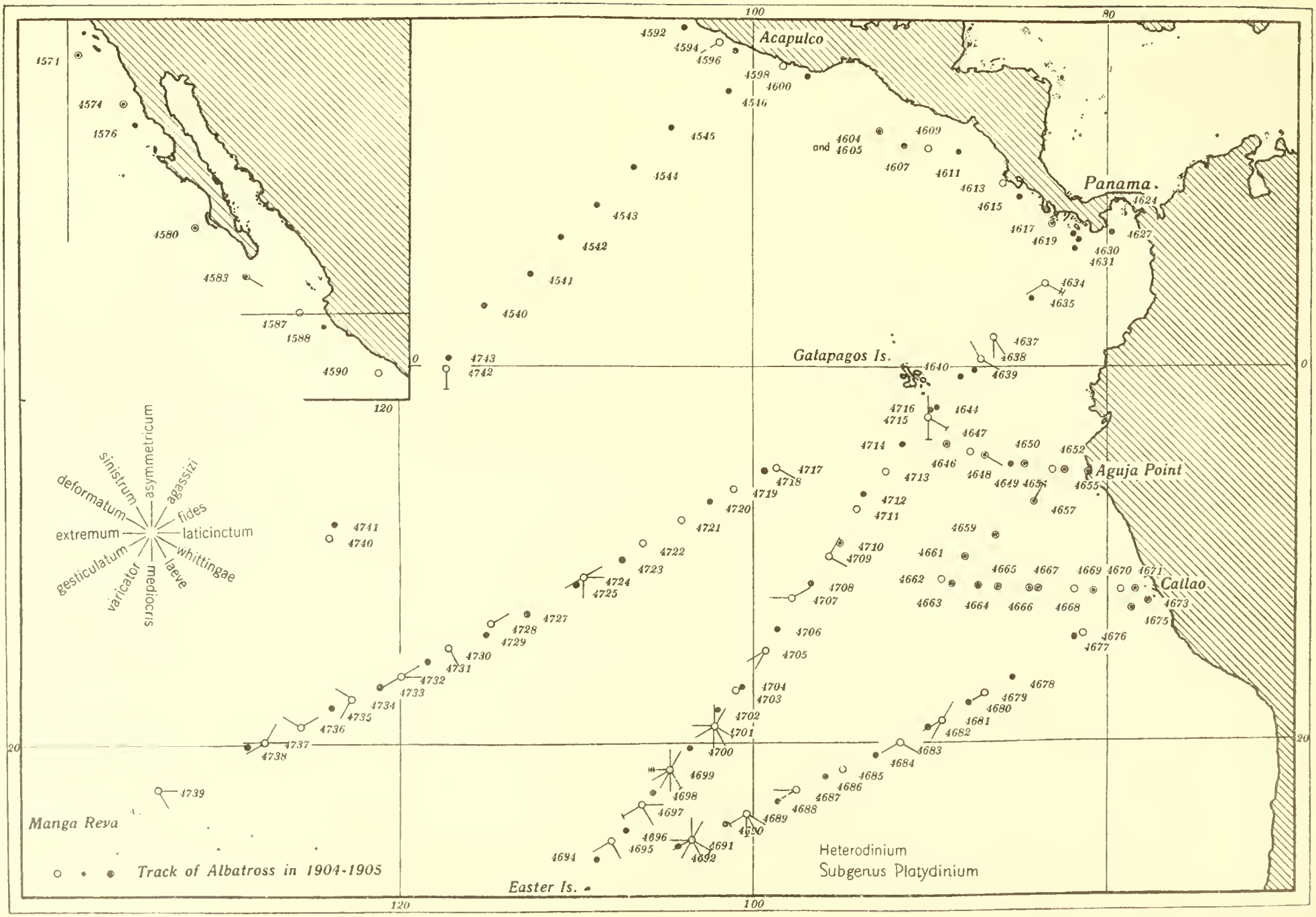


MEIOTYPE CORP. BOSTON

PLATE 14

PLATE 14.

Map of distribution of species of Heterodinium belonging to the subgenus Platydinium. See explanation of Plate 13 for explanation of symbols.



HELIOTYPE CORP. BOSTON

PLATE 15

PLATE 15.

Figures 1–25. — Species of the genus Heterodinium arranged in subgenera, Sphaerodinium, Heterodinium, and Platydinium, and in species groups, all drawn in ventral view, except as noted, and to the same magnification, namely, 200 diameters. In figures copied from other authors, the probable positions of certain sutures between plates, are indicated by dotted lines.

Subgenus Sphaerodinium.

Kofoidi group.

Fig. 1. *H. kofoidi* Schiller (1916, fig. 2). Adriatic.
Fig. 2. *H. sphaeroideum* Kofoid (1906a, pl. 3, fig. 15). San Diego.
Fig. 3. *H. doma* (Murray and Whitting, 1899) Kofoid (1906a). Station 4691.
Fig. 4. *H. calvum* Kofoid (1907a, pl. 7, fig. 43). Station 4739.

Minutum group.

Fig. 5. *H. minutum* Kofoid and Michener (1911, p. 285). Station 4697.
Fig. 6. *H. obesum* Kofoid (1906a, pl. 8, fig. 50). Station 4734.
Fig. 7. *H. murrayi* Kofoid (1906a, p. 353). Station 4722.
Fig. 8. *H. milneri* (Murray and Whitting, 1899) Kofoid (1906). Station 4734.
Fig. 9. *H. superbum* Kofoid (1907a, pl. 8, fig. 49). Station 4699.
Fig. 10. *H. globosum* Kofoid (1907a, pl. 8, fig. 51). Station 4699.

Subgenus Heterodinium.

Expansum group.

Fig. 11. *H. expansum* Kofoid (1907a, pl. 6, fig. 36). Station 4637.
Fig. 12. *H. angulatum* Kofoid and Michener (1911, p. 285). Station 4691. Dorsal view.
Fig. 13. *H. spiniferum* Kofoid and Michener (1911, p. 286). Station 4695.
Fig. 14. *H. fenestratum* Kofoid (1907a, pl. 8, fig. 47). Station 4730.
Fig. 15. *H. praetextum* Kofoid (1907a, pl. 7, fig. 41). Station 4740.

Rigdenae group.

Fig. 16. *H. rigdenae* Kofoid (1906a, pl. 18, fig. 6). San Diego.
Fig. 17. *H. crassipes* Schiller (1916, p. 210, fig. 1). Adriatic.
Fig. 18. *H. scrippsi* Kofoid (1906a, pl. 17, fig. 1). San Diego.
Fig. 19. *H. trirostre* (Murray and Whitting, 1899, pl. 29, fig. 5). Kofoid (1906a).

Dispar group.

Fig. 20. *H. dispar* Kofoid and Adamson. Station 4683.
Fig. 21. *H. elongatum* Kofoid and Michener (1911, p. 284). Station 4732.
Fig. 22. *H. leiorhynchum* (Murray and Whitting, 1899) Kofoid (1906a). From Murray and Whitting, 1899, pl. 29, fig. 2a.
Fig. 23. *H. hindmarchii* (Murray and Whitting, 1899) Kofoid (1906a). Station 4689.
Fig. 24. *H. curvatum* Kofoid (1907a, pl. 8, fig. 48). Station 4699.
Fig. 25. *H. blackmani* (Murray and Whitting, 1899) Kofoid (1906a). Station 4724.

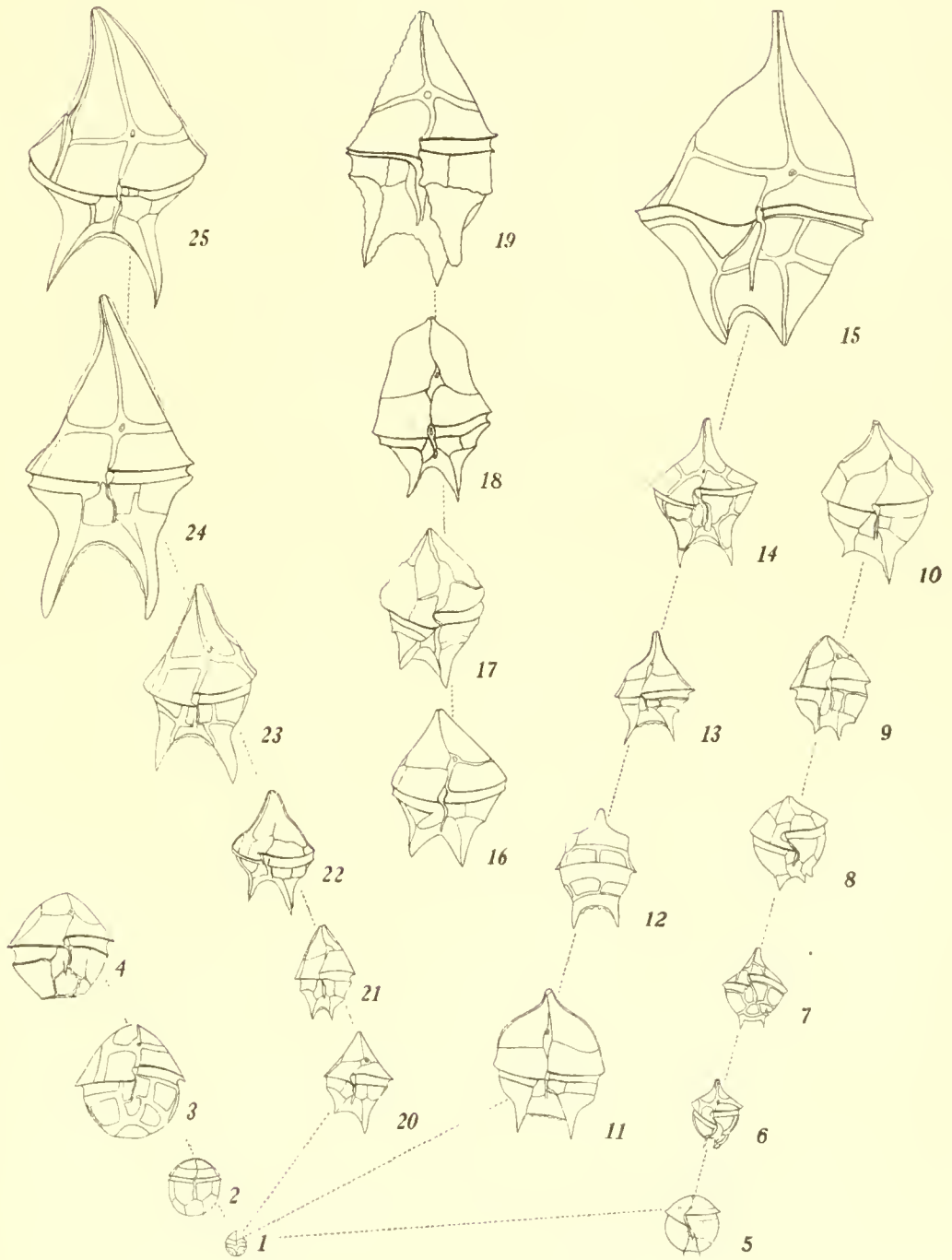


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PLATE 16

PLATE 16.

Figures 26–40. — Species of the genus Heterodinium, subgenus Platydinium, arranged in groups, all drawn in ventral view, except as noted, and to the same magnification, namely, 200 diameters.

Subgenus Platydinium.

Pavillardi group.

Fig. 26. *H. pavillardi* Kofoid and Adamson. After Pavillard (1916, pl. 2, fig. 2). Gulf of Lyons.

Fig. 27. *H. agassizi* Kofoid (1907a, pl. 6, fig. 35). Station 4699.

Fig. 28. *H. fides* Kofoid (1907a, pl. 7, fig. 45). Station 4728.

Fig. 29. *H. whittingae* Kofoid (1906a, pl. 19, fig. 11). California Current.

Fig. 30. *H. laticinctum* Kofoid (1907a, pl. 7, fig. 46). Station 4724.

Fig. 31. *H. asymmetricum* Kofoid and Adamson. Station 4701. Dorsal view.

Fig. 32. *H. inaequale* Kofoid (1906a, pl. 18, fig. 91). San Diego.

Fig. 33. *H. laeve* Kofoid and Michener (1911, p. 284). Station 4639.

Gesticulatum group.

Fig. 34. *H. sinistrum* Kofoid and Adamson. Station 4638.

Fig. 35. *H. deformatum* Kofoid (1907a, pl. 8, fig. 40). Station 4724.

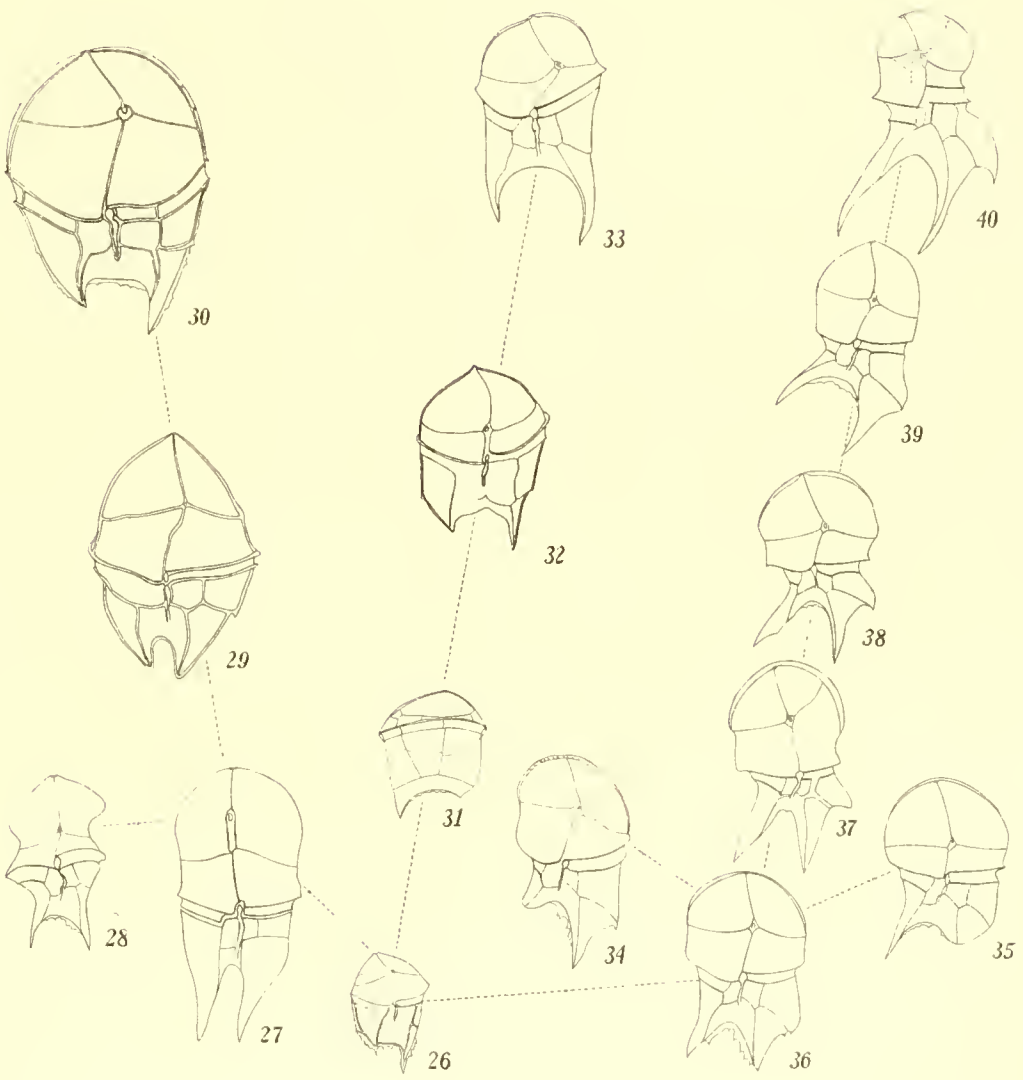
Fig. 36. *H. mediocre* Kofoid (1907a, pl. 6, fig. 39). Station 4724.

Fig. 37. *H. gesticulatum* Kofoid (1907a, pl. 6, fig. 37). Station 4699.

Fig. 38. *H. extremum* Kofoid (1907a, pl. 8, fig. 38). Station 4699.

Fig. 39. *H. varicator* Kofoid and Adamson. Station 4699.

Fig. 40. *H. scotti* Kofoid and Adamson. After Wilson (1905) in Scott (1905, vol. 2, plate facing p. 192).



HELIOTYPE CORP. BOSTON

PLATE 17

PLATE 17.

Fig. 41. Distribution of *Heterodinium curvatum* (marked by circles) and *Dolichodinium lineatum* (marked by squares). Large solid circles and squares indicate locations of stations with records from vertical or intermediate hauls. Large open circles indicate locations of stations with records from surface hauls. Small open circles mark locations of stations at which these species were not found.

Figures 42–47. *Heterodinium rigdenae* Kofoid. × 500.

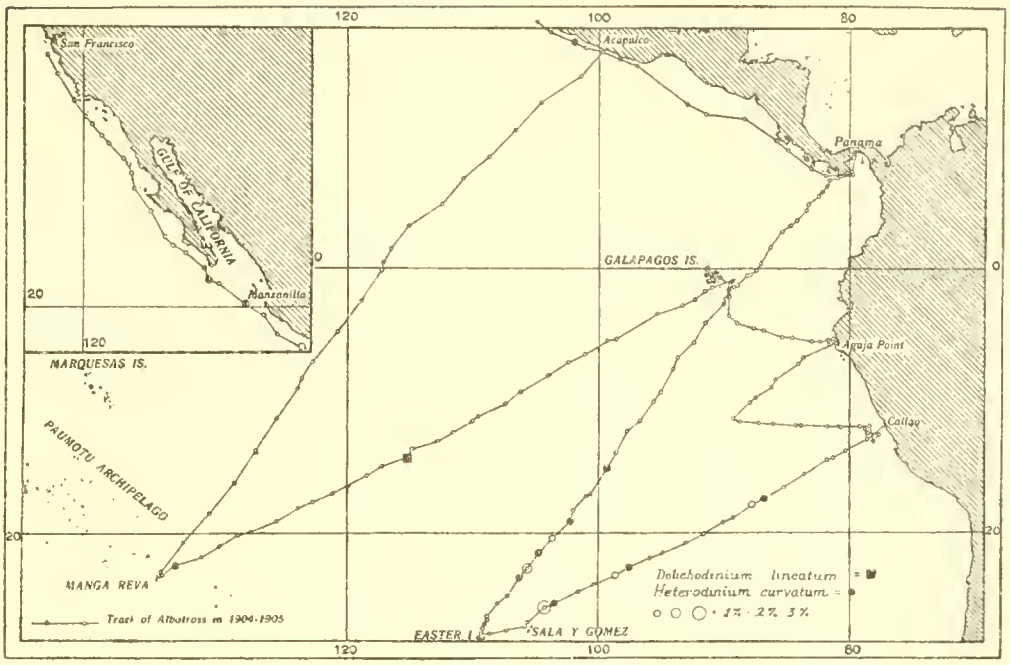
Fig. 42–44. Ventral views. Stations 4724, 4732, 4734, respectively (300–0 fathoms).

Fig. 45. Dorsal view of specimen with more of an apical horn and shorter antapical than are normally present, tentatively referred to this species. Station 4742 (300–0 fathoms).

Fig. 46. Ventral view. Station 4638 (300–0 fathoms).

Fig. 47. Dorsal view. Station 4613 (300–0 fathoms).

Plates labelled as follows on Figures 42 and 45: — apical plates, 1′–3′; anterior intercalary plate, 1ª; precingular plates, 1″–6″; postcingular plates, 1‴–7‴; antapical plates, 1⁗–3⁗.



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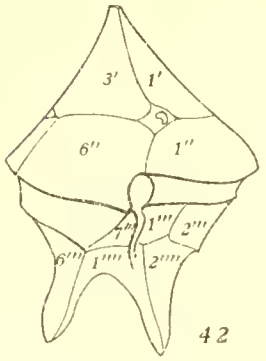

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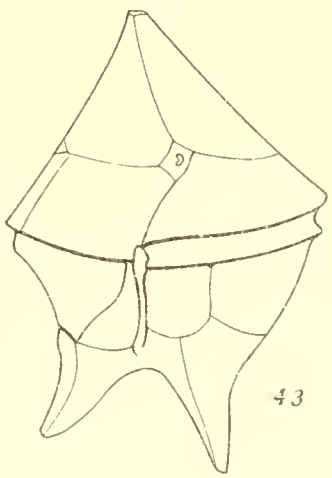

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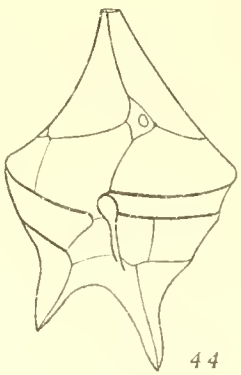

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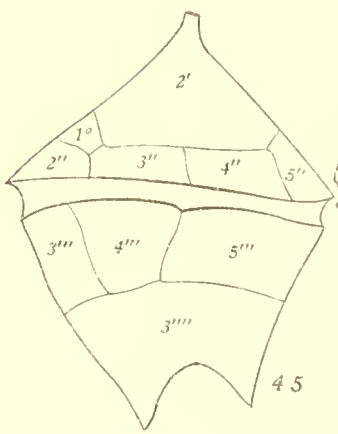

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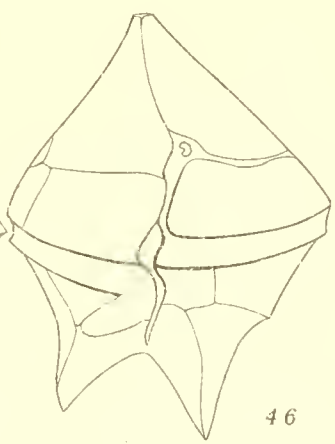

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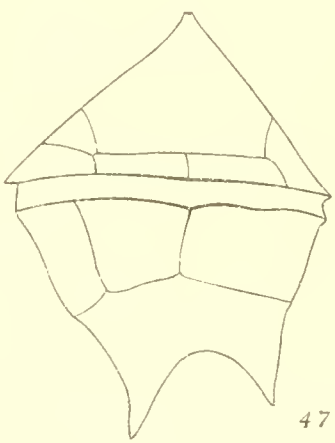

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PLATE 18

PLATE 18.

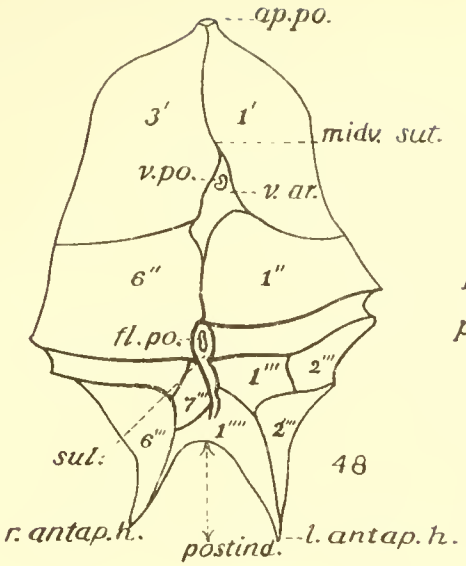
Figures 48–51. Plates of *Heterodinium scrippsi* Kofoid (1906a, pl. 17, fig. 1–4). × 500. From California Current, off San Diego.

Fig. 48. Ventral view.
Fig. 49. Dorsal view.
Fig. 50. Oblique left lateral view.
Fig. 51. Apical view.

Figs. 52–55. Plates of *Heterodinium laticinctum* Kofoid. × 500. Station 4724 (300–0 fathoms).

Fig. 52. Ventral view.
Fig. 53. Left lateral view.
Fig. 54. Dorsal view.
Fig. 55. Right lateral view.

Abbreviations: — *ap. po.*, apical pore; *fl. po.*, flagellar pore; *fur.*, furrow; *l. antap. h.*, left antapical horn; *midv. sut.*, midventral suture; *postind.*, postindentation; *postm.*, postmargin; *poste. l.*, postcingular ledge; *prec. l.*, precingular ledge; *r. antap. h.*, right antapical horn; *sul.*, sulcus; *v. ar.*, ventral area; *v. po.*, ventral pore; girdle plates, 1–7; apical plates, 1′–3′; anterior intercalary plate, 1ª; precingular plates, 1″–6″; postcingular plates, 1‴–7‴; antapical plates, 1⁗–3⁗.



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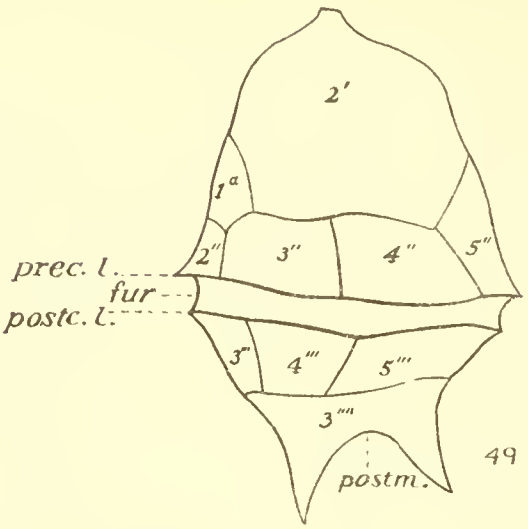

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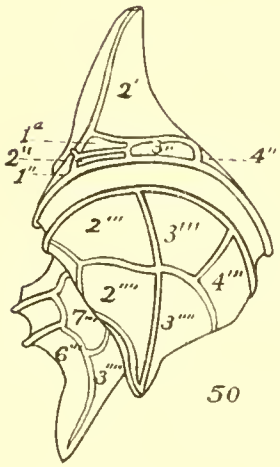

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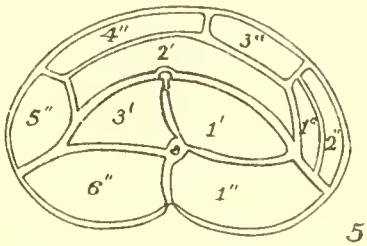

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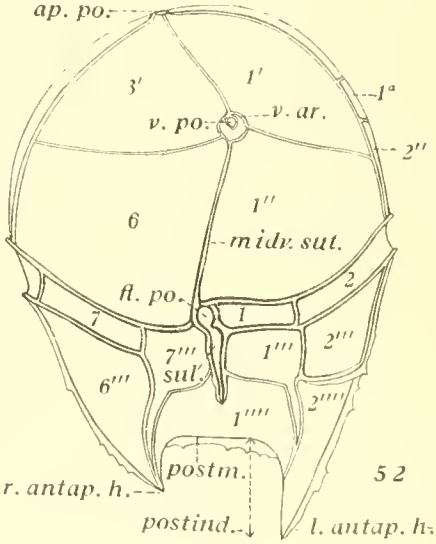

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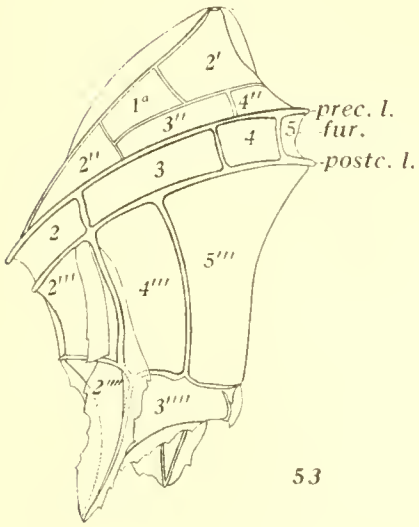

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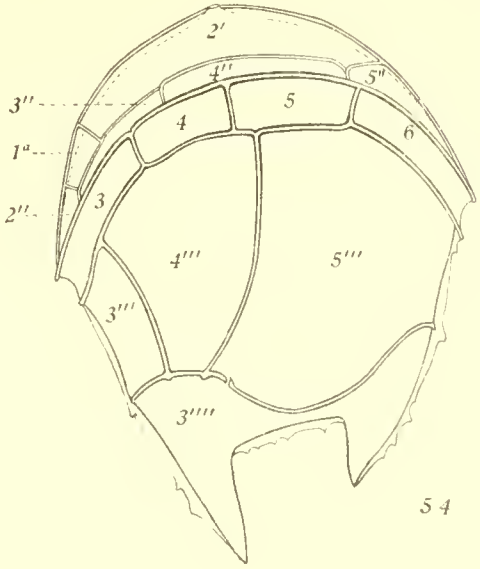

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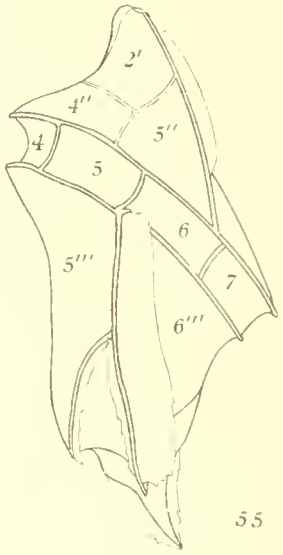

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HELIOTYPE CORP. BOSTON

PLATE 19

PLATE 19.

Figs. 56–58. *Heterodinium fides* Kofoid. × 500.

Fig. 56. Ventral view. Station 4638 (300–0 fathoms).

Fig. 57. Left lateral view. Station 4728 (300–0 fathoms).

Fig. 58. Dorsal view of the same.

Figs. 59–65. *Heterodinium mediocre* (Kofoid). × 675.

Fig. 59–61. Ventral views of different loricae from Station 4742 (300–0 fathoms).

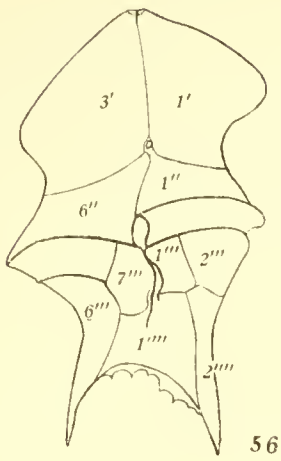
Fig. 62. Dorsal view. Station 4637 (300–0 fathoms).

Fig. 63. Dorsal view. Station 4724 (300–0 fathoms).

Fig. 64. Ventral view. Station 4699 (300–0 fathoms).

Fig. 65. Dorsal view, outline of spherical nucleus dotted in. Station 4742 (300–0 fathoms).

Plates labelled on Figures 59 and 63 as follows: — apical plates, 1′–3′; anterior intercalary plate, 1ª; precingular plates, 1″–6″; postcingular plates, 1‴–7‴; antapical plates, 1⁗–3⁗.



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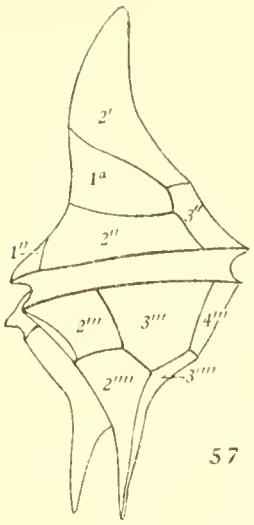

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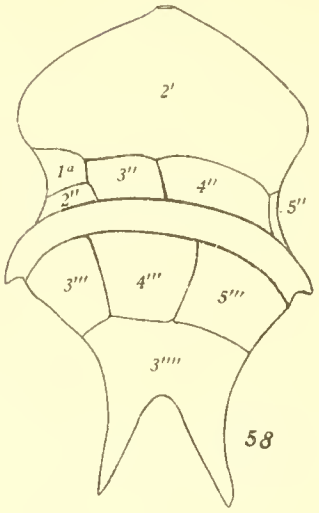

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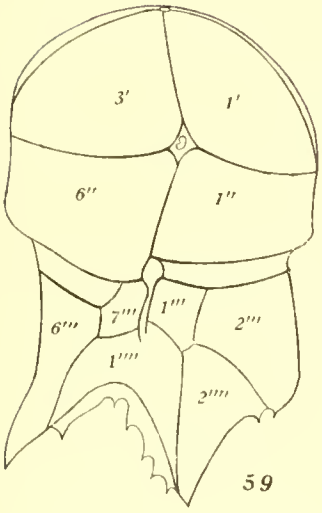

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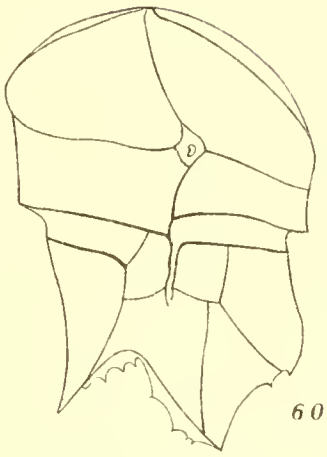

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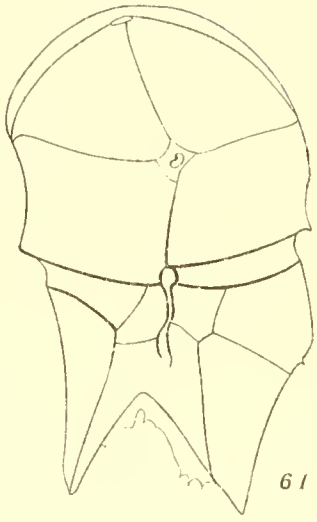

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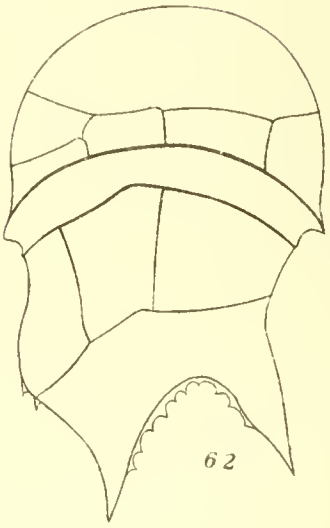

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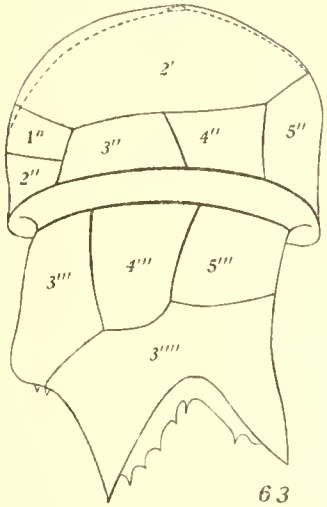

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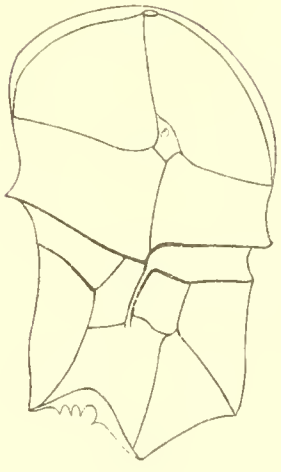

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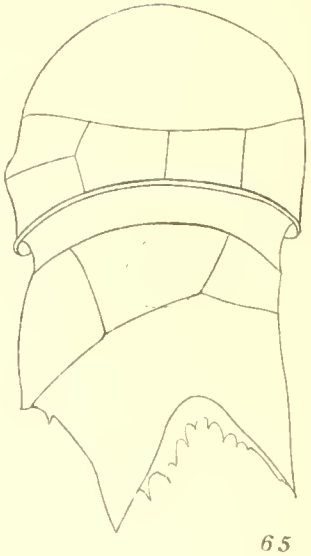

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HELIOTYPE CORP. BOSTON

PLATE 20

PLATE 20

Figs. 66–72. *Heterodinium varicator* Kofoid and Adamson. × 500.

Fig. 66. Dorsal view. Station 4691 (300–0 fathoms).

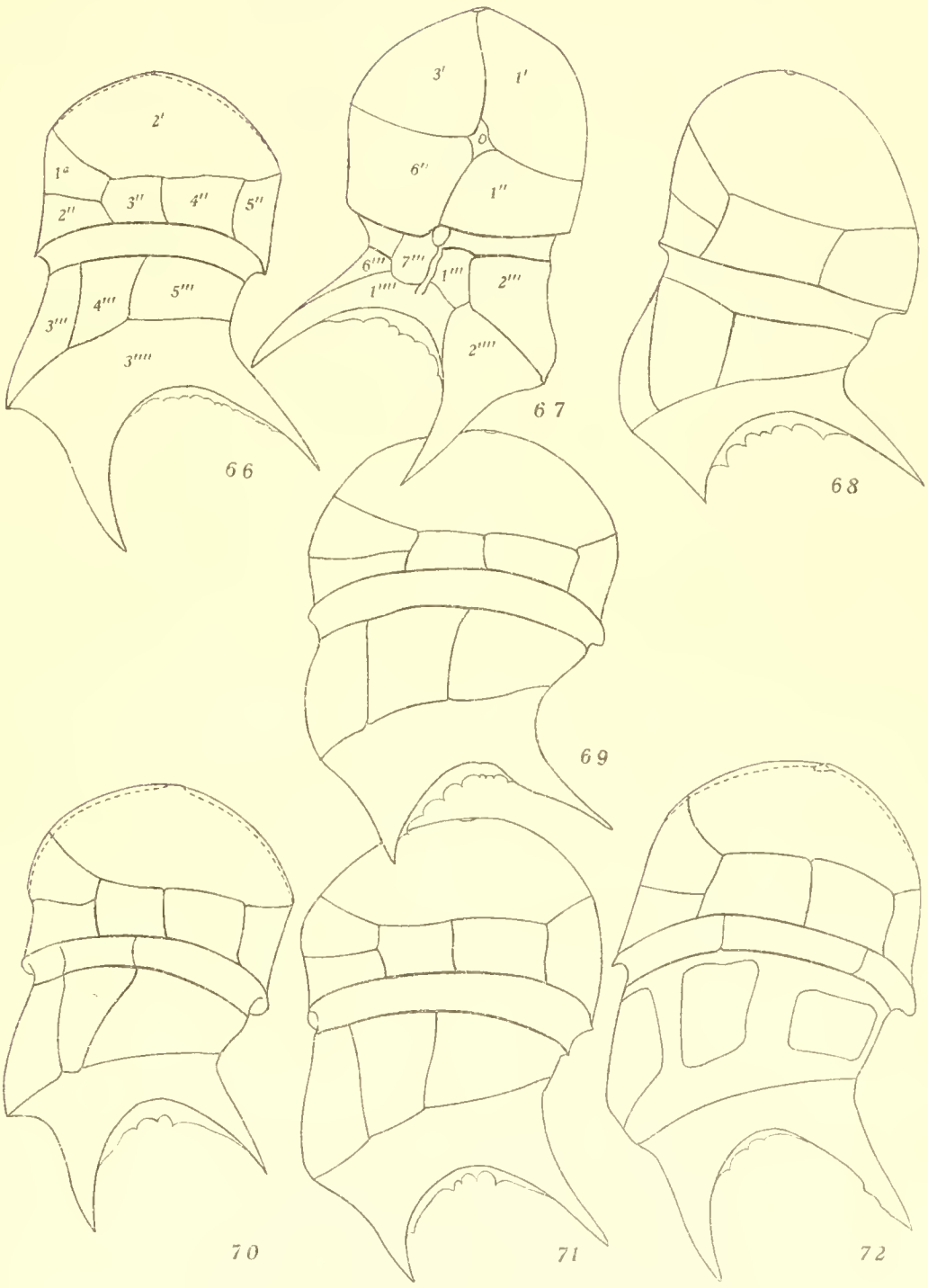
Fig. 67. Ventral view. Station 4699 (300–0 fathoms).

Fig. 68. Dorsal view of *forma distortum* Kofoid and Adamson. Station 4681 (800–0 fathoms).

Fig. 69. Dorsal view. Station 4734 (300–0 fathoms).

Fig. 70–72. Dorsal views. Stations 4705, 4734, 4691, respectively (300–0 fathoms).

Plates labelled on Figures 66 and 67 as follows: — apical plates, 1′–3′; anterior intercalary plate, 1ª; precingular plates, 1″–6″; postcingular plates, 1‴–7‴; antapical plates, 1⁗–3⁗.



HELIOTYPE CORP. BOSTON

PLATE 21

PLATE 21.

Figs. 73–78. Species of Heterodinium related to *H. gesticulatum*. × 500.

Fig. 73. *Heterodinium deformatum* (Kofoid), dorsal view. Station 4720 (300–0 fathoms)

Fig. 74. *Heterodinium mediocre* (Kofoid), ventral view. Station 4689 (300–0 fathoms).

Fig. 75. *Heterodinium deformatum* (Kofoid), ventral view. Station 4724 (300–0 fathoms).

Fig. 76. *Heterodinium deformatum* (Kofoid), dorsal view. Station 4736 (300–0 fathoms).

Fig. 77. *Heterodinium agassizi* Kofoid, ventral view; hypotheca detached from girdle at girdle-postcingular suture showing arrow-shaped process from postcingular 7′″ running towards flagellar pore. Station 4731 (300–0 fathoms).

Fig. 78. *Heterodinium sinistrum* Kofoid and Adamson, ventral view. Station 4638 (300–0 fathoms).

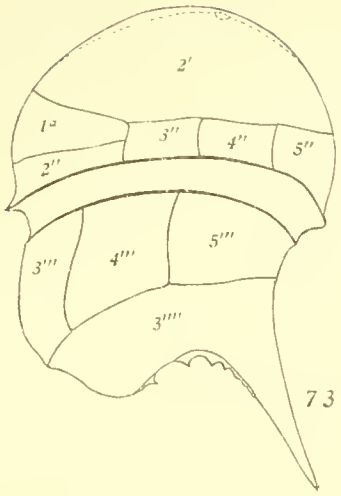
Plates of *H. deformatum* are labelled on Figure 73 and of *H. mediocre* on Figure 74 as follows: — apical plates, 1′–3′; anterior intercalary plate, 1ª; precingular plates, 1″–6″; postcingular plates, 1‴–7‴; antapical plates, 1⁗–3⁗.

Figs. 79–81. *Heterodinium extremum* (Kofoid). × 500.

Figs. 79, 80. Dorsal views. Stations 4699, 4707 (300–0 fathoms).

Fig. 81. Ventral view. Station 4699 (300–0 fathoms).

Plates labelled on Figures 80 and 81 as follows: — apical plates, 1′–3′; anterior intercalary plate, 1ª; precingular plates, 1″–6″; postcingular plates, 1‴–7‴; antapical plates, 1⁗–3⁗.



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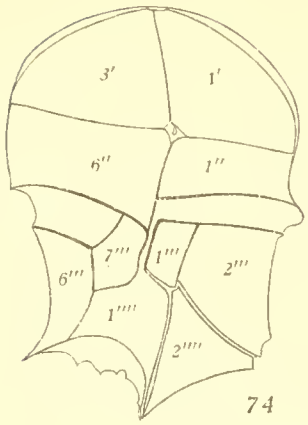

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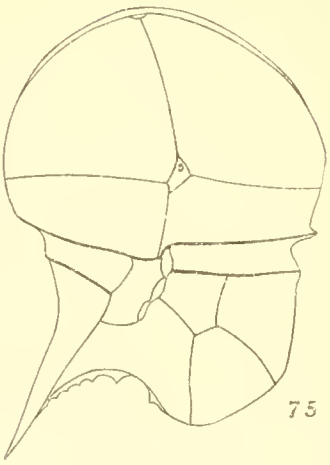

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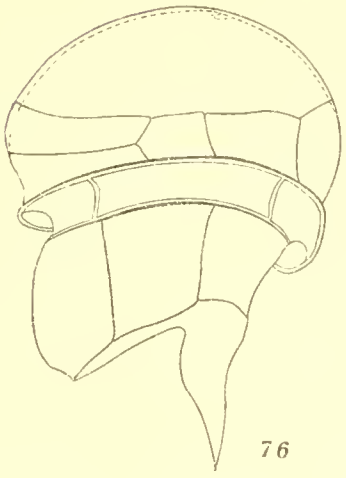

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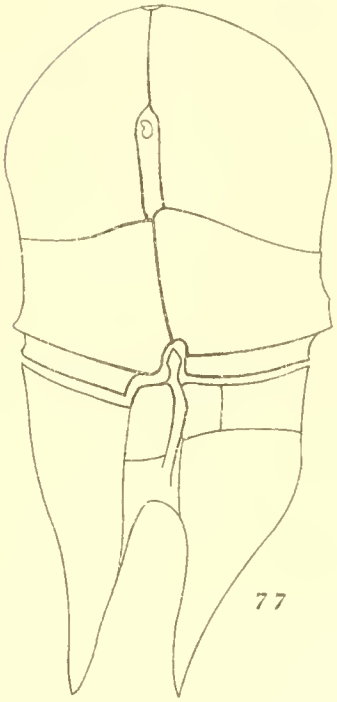

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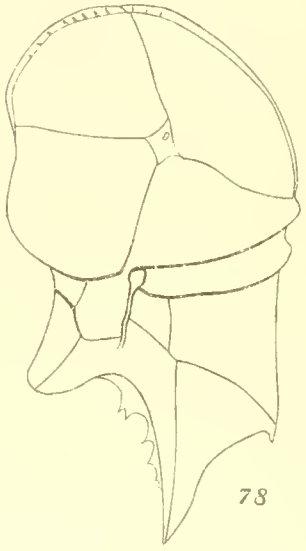

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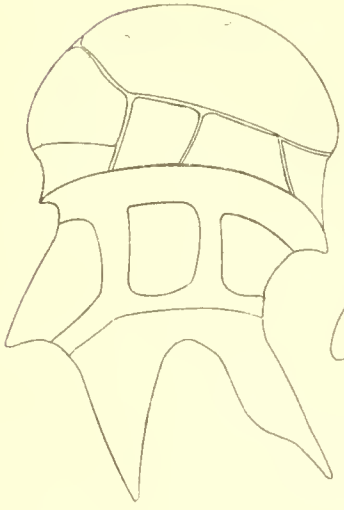

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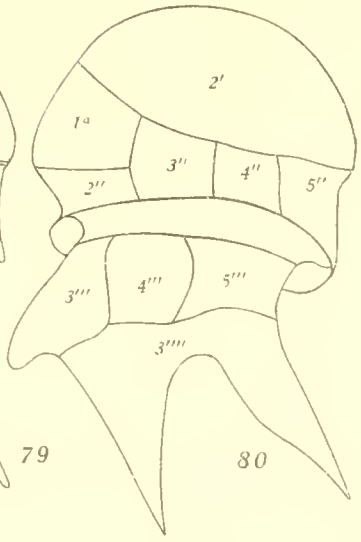

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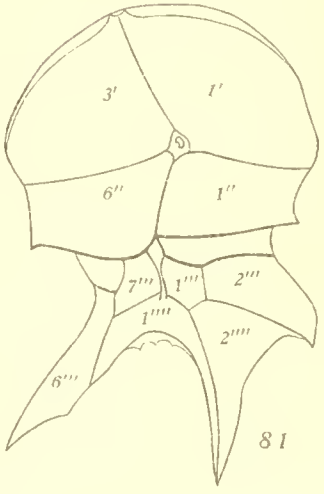

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PLATE 22

PLATE 22.

Figs. 82–84. *Heterodinium extremum* (Kofoid). × 500.

Fig. 82. Ventral view. Station 4699 (300–0 fathoms).

Figs. 83, 84. Dorsal views. Stations 4691 and 4687 (300–0 fathoms).

Fig. 85. *Heterodinium scotti* Kofoid and Adamson. Ventral view, after a figure by E. A. Wilson in Scott (1905, vol. 2, plate facing p. 192). In this figure all suture lines on the ventral face are drawn as in Wilson's figure. Those which he drew as on the ventral face, but which we interpret as dorsal, are represented by dashes. Sutures whose location we conjecture are dotted in, as in the sulcus, plate 7″ ′, and the ventral area.

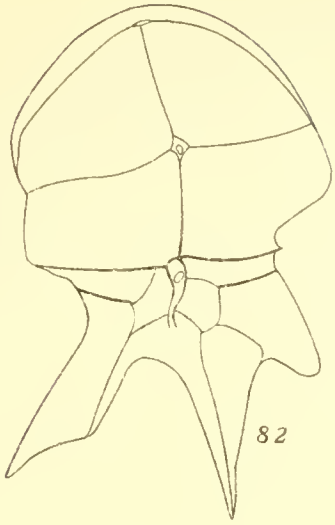
Fig. 86. *Heterodinium gesticulatum* Kofoid. Ventral view. Station 4691 (300–0 fathoms). × 500.

Figs. 87, 88. *Dolichodinium lineatum* (Kofoid and Michener), type specimen. Station 4701. × 1000.

Fig. 87. Ventral view.

Fig. 88. Dorsal view.

Abbreviations: ap. po., apical pore; *fl. po.*, flagellar pore; *gird.*, girdle; *prec. r.*, precingular ridge; *postc. r.*, posteingular ridge; *sul.*, sulcus; *v. po.*, ventral pore. Plates labelled as follows: — girdle plates, 1–6; apical plates, 1′–4′; precingular plates, 1″–6″; posteingular plates, 1″ ′–6″ ′; antapical plates, 1″ ″–3″ ″.



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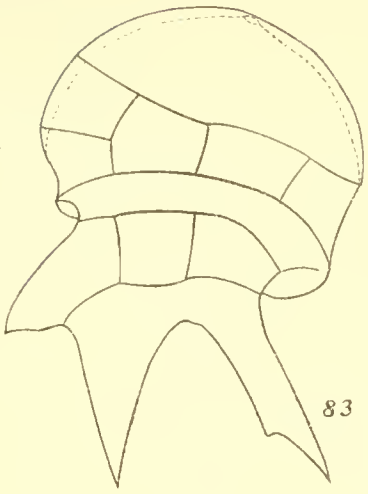

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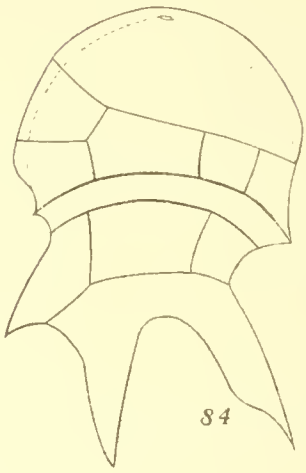

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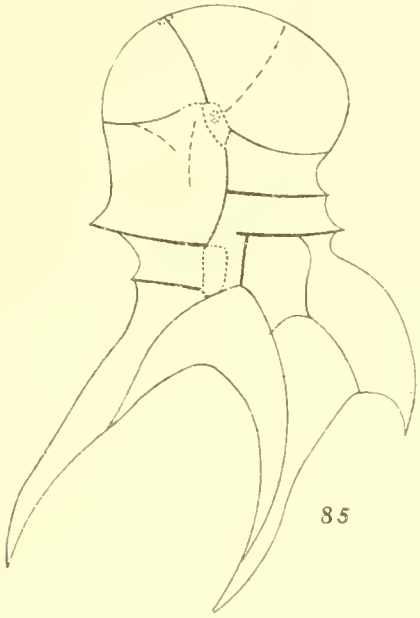

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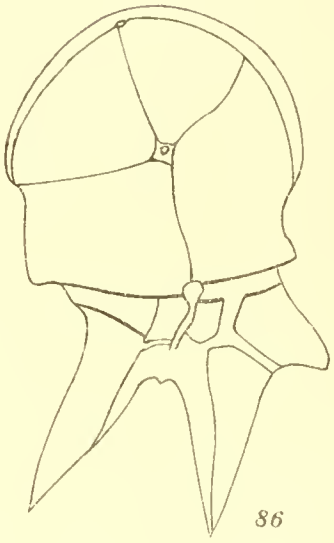

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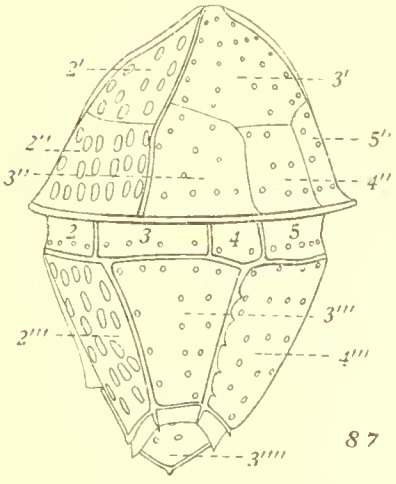

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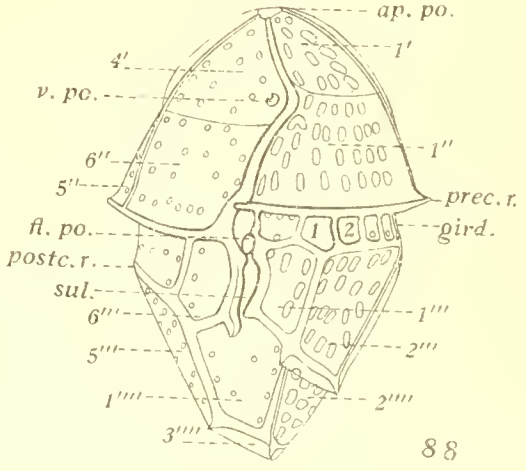

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HELIOTYPE CORP., BOSTON

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